AD 273 677

REPORT NO.
TDR-930(2701-01)TN-1
PART I, NO. 5

Applied Research Management

Abstract Bulletin

(Part I)

Abstracts 1-961 through 1-1103

NOVEMBER 1961

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Prepared for DEPUTY COMMANDER AEROSPACE SYSTEMS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Inglewood, California

AEROSPACE CORPORATION
CONTRACT NO. AF 04(647)-930

Report No.
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ABSTRACT

Part I, No. 5 is a bibliography, with abstracts, from unclassified literature presented on the subject of Flight Vehicle Power. Selected references in the field of materials are also included. All references are to primary sources.

Approved by K. B. Andrews
K. B. Andrews
Literature Research Group

AEROSPACE CORPORATION
El Segundo, California

SUBJECT INDEX

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

SUBJECT INDEX (Continued)

AUTHOR INDEX

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Continued)

AUTHOR INDEX (Concluded)

SOURCE INDEX

SOURCE INDEX (Continued)

SOURCE INDEX (Continued)

SOURCE INDEX (Concluded)

I. FLIGHT VEHICLE POWER

SECTION A - GENERAL

1-961. ADVENTURES IN ENERGY CONVERSION. R. W. Porter. J. Amer. Soc. Naval Engrs., vol. 73, no. 1, Feb. 1961, p. 29-36.

This article by R. W. Porter is based on remarks made at a symposium held by American Institute of Electrical Engineers (AIEE) on "Exploring the Future of Direct Energy Conversion." It describes briefly and presents the schematics of the following areas of energy conversion which look promising: fuel cells (including ion-membrane fuel cell), thermoelectric conversion (thermoelectric generators), thermionic conversion, magnetohydrodynamic converters (closed-cycle MHD generators for continuous operation in space and open-cycle MHD generators for short burst of electric power). In conclusion, some considerations are presented on organization and financing in the field of energy conversion.

1-962. DIRECT ENERGY CONVERSION LITERATURE ABSTRACTS. Naval Research Lab., Washington, D. C. Mar. 1961. 111p. AD 255 294. A61-7778.

This report consists of 547 abstracts which cover the following areas of direct energy conversion:

Energy Conversion
Thermoelectricity
Thermionic Emission
Photoelectric Processes
Magnetohydrodynamics
Electrochemical Processes
Energy Storage
Energy Sources

The majority of the publications referred to should be available for consultation or borrowing at the larger public or research libraries. Translations when referenced, are usually indicated to be available from Special Libraries Association Translation Center, located at the John Crerar Library, 86 East Randolph Street, Chicago, Illinois.

1-963. POWER SOURCES CONFERENCE, 15TH ANNUAL, PROCEEDINGS, 9-11 May 1961. Army Signal Research and Development Lab., Fort Monmouth, N. J. 162p. illus. QC 603. U58, 1961.

Contents:

Welcoming Address, by Col. R. A. Bates

The following sessions were held:

Research in the Department of the Army
Primary Fuel Cell Batteries
Regenerative Fuel Cell Batteries
Secondary Batteries
Primary Batteries
Solar Energy Conversion
Thermal Energy Conversion

1-964. TRENDS IN AUXILIARY POWER. S. Peter Kaprielyan and Marcus Ainsworth. Aerospace Management, vol. 4, no. 8, Aug. 1961, p. 50-3.

This paper discusses briefly airborne-power requirements for aircraft, both commercial and military, and for space vehicles where the need for electrical power is especially acute. A diagram and a table of forms of energy sources and energy conversion techniques are given. A list of aerospace power units is compiled in the form of a table which gives the make and model, stage of progress, overall dimensions, performance, fuel, operating cycle and application of power units, both existing and under development. Foreseeable tasks of space power systems include: vehicle attitude control, propulsion system actuation, operation of communication systems and of tracking beacons, orientation of telescopes, operation of vehicles on the moon and planets, control of internal environment, and the fulfillment of numerous tasks by robot systems. Finally, some future developments and problem areas faced by various organizations engaged in auxiliary power research are described.

1-965. UNCONVENTIONAL METHODS OF ENERGY CONVERSION.
Nature, vol. 192, no. 4804, 25 Nov. 1961, p. 701-03

This paper discusses briefly the reports presented at a joint session of the Mathematics and Physics Section and the Engineering Section of the British Association held in Norwich in 1961 to discuss the need for new methods and the principles for new methods of converting heat into electricity. In the opening paper, Professor T. G. Cowling (University of Leeds) pointed out that with established methods of using solar energy indirectly, by fossil fuel or by water-power, the proportion of the incident energy which is utilized for energy conversion is extremely small. For the new methods of utilizing existing sources of energy, those of interest appear to be thermoelectricity, the thermionic diode, magnetohydrodynamics and the fuel cell. Mr. F. H. S. Brown (Central Electricity Generating Board) considered the incentives for establishing unconventional methods of energy conversion. The problem remaining with conventional methods is the conversion of heat to mechanical energy. Here, the steam cycle is more satisfactory than the internal combustion engines, although it has a limiting temperature near 600° C. The efficiency obtainable is about 40%. It is clear that it would be very desirable to increase overall efficiency above 40%, and the methods of achieving this could in principle be: 1) finding an intermittent process cheaper and more reliable than the internal combustion engine; 2) evolving better materials
(cont.)

1-965. (Cont.)

for use at high temperatures (e.g., up to 1700° C); 3) evolving a continuous method which does not stress working parts at high temperature. In the third paper Dr. R. G. Siddall (University of Sheffield) described the work of Professor M. W. Thring and himself on producing electricity directly from fast-moving plasmas. Three ideas due to Professor Thring are under investigation. First, continuous combustion at 2500° C followed by expansion through a nozzle is used to produce the high velocity. Secondly, short bursts of preheated oxygen and fuel seeded with potassium are injected periodically into the combustion chamber immediately before the expansion nozzle. The third idea utilizes shock waves produced successively at the opposite ends of a tube, so driving a plasma to and fro through the magnetic field. Mr. P. Dunn (Atomic Energy Research Establishment) described the basic principles of the thermionic diode as an energy converter which can be conveniently used with fission nuclear power, as it is easy to obtain the required heat flux to the cathodes. In the final paper, Professor D. A. Wright (University of Durham) discussed thermoelectricity as a means of generating power directly from heat and showed why the performance of metallic thermojunctions was poor. It would be possible to make low-resistance reliable contacts and the material must not melt or decompose in operation. One of the best materials so far is bismuth-antimony-telluride.

SECTION B - CHEMICAL SOURCES OF ENERGY

1-966. AN ANALYSIS OF POWER DISTRIBUTION RELATIVE TO THE DESIGN OF HIGH ENERGY DENSITY BATTERIES. William C. Spindler. Naval Ordnance Lab., Corona, Calif. Research Dept., NAVWEPS Rept. 7184. 15 July 1961. 24p. AD 260 002. A61-11018.

An analysis is presented of the important aspects of power distribution between a generator and its load, with respect to operating current density, when rapid, high-energy transfer is required. The general equations are developed for the basic ohmic circuit and are illustrated for a 1200-watt battery application. Various representations of transfer efficiency are examined, and an optimum power transfer point is defined at approximately half the current density required for maximum load power. The effects of polarization characteristics on maximum power transfer are briefly discussed. The study shows that the theoretical limit of 25% which applies to linearly polarized systems can be exceeded for higher order polarization (such as cubic), but may not reach that limit for lower order polarization (such as logarithmic).

1-967. EVALUATION OF THE PERFORMANCE AND RELIABILITY OF THE BATTERY BA-481( )/U. VOLUME II. MANUFACTURING SPECIFICATIONS AND DRAWINGS. Supplement to Final Report, 9 June 1958-30 June 1960. Eagle-Picher Co., Joplin, Mo. Contract: DA-36-039-SC-78061. A61-8843, Supplement.

This volume is a supplement to the Final Report, Volume I, and contains manufacturing specifications and drawings of the battery BA-481( )/U.

1-968. FEASIBILITY STUDY ON HIGH PERFORMANCE, SHORT DURATION POWER BATTERIES. Twelfth Quarterly Technical Progress Report, 15 Mar.-15 June 1961. Union Carbide Consumer Products Co. Research Lab. Parma, Ohio. 14p. Contract: NOrd-18240. A61-10322.

The diffusion coefficient of silver was run again and found to differ from the data supplied by Gruen by a factor of 7. Since this was still of the same order of magnitude as Gruen's result, and since the chemical method of analysis was being used to its limit of accuracy, the experiment will be rerun using radioactive tracer techniques for increased sensitivity. Approximately 250 test cells, principally involving CuO, various sulfates and phosphates, have been prepared and evaluated. Based on active material alone (anode weight plus the calculated amount of cathodic material for complete reaction) CuO gave a maximum of 282 watt-hrs/lb; the phosphates gave a maximum of 256 watt-hrs/lb, and the sulfates gave a maximum of 310 watt-hrs/lb. On the basis of total balanced cell weight, the phosphates gave a maximum of 175.1 watt-hrs/lb while the sulfates gave a maximum of 141 watt-hrs/lb; CuO on the same basis gave 182.4 watt-hrs/lb.

1-969. FUEL CELL AND ITS RELATED TECHNOLOGY. I. CORRELATION BETWEEN MAGNETIC SUSCEPTIBILITY AND CATALYTIC ACTIVITY OF ELECTRODE. Ju Chin Chu and S. M. Hu. Final Report, 16 July 1960-15 July 1961. Brooklyn. Polytechnic Inst. Chemical Engineering Dept. 69p. illus. Contract: DA-44-009-ENG-4586. 40 refs. A61-10323.

Magnetic susceptibility serves as a good index for catalytic activity of the half-cell electrode in a fuel cell. To clarify the basic mechanism involved, the theory of magnetism was outlined with a brief account of the molecular field theory of paramagnetism and domain theory of ferromagnetism. Due discussion was given on ferromagnetism in thin film as a necessary prior knowledge in experimentation. Phenomena associated with thin films are the uncertainty in the decrease of magnetization, transition of magnetism type and thickness limitation for the ferromagnetism. Contamination, notably oxygen, of the ferromagnetic film has a marked effect on the magnetic property. The control mechanism for the catalytic reaction at the electrode is postulated to involve chemisorption. The rate equation for chemisorption is analyzed. The transient behaviors of magnetic susceptibility and fraction of unoccupied active sites are shown to be related to one another. Rate coefficients for chemisorption are expressed in terms of the magnetic susceptibility change. Necessary information (cont.)

1-969. (Cont.)

is analyzed and the method of data interpretation is described in sufficient detail. For the measurement of magnetic susceptibility, three methods were proposed. The first two give simultaneous emf and magnetic susceptibility measurement. The two methods are known as proton resonance and torque magnetometer. The latter was aimed to avoid air contamination and to provide greater certainty of measuring accuracy. It is a modification of the one used by Neugebauer in the measurement of saturation magnetization of the thin films below 100° A. The apparatus is detachable through Teflon gasket joints. Connection is provided for mounting on the vacuum deposition setup. Dynamic emf can be measured for various current densities. The chief disadvantage of the method is high cost and inability to follow transient state. The method finally adopted for the magnetic susceptibility measurement is a modified version of Gouy's method. With an Ainsworth automatic recording balance, the transient data can be measured in a closed system. The experimental setup, which involves an electromagnet, a chemisorption cell, a force measuring system, a vacuum system, a gas system, and temperature measurement and controls, has been completed. The mechanical details and complete layout as well as theoretical analyses are fully described in the report.

1-970. FUEL CELL AND ITS RELATED TECHNOLOGY. II. CORRELATION BETWEEN INFRARED SPECTRUM AND CATALYTIC ACTIVITY OF ELECTRODE. Ju Chin Chu and W. S. Yu. Final Report, 16 July 1960-15 July 1961. Brooklyn. Polytechnic Inst. Chemical Engineering Dept. 30p. illus. Contract: DA-44-009-ENG-4586. 21 refs. A61-10324.

The application of infrared to the catalytic study for the fuel cell electrode was reviewed and emphasis was placed especially upon chemisorption. Transmission and reflection methods are two well-known techniques in obtaining an infrared spectrum. In this report two optical systems employing reflection technique have been presented. However, a large number of catalyst mirrors would be required in order to obtain a measurable spectrum. It appears that the reflection technique is not only an extremely expensive but also an impractical installation for the catalyst investigation. There are several techniques which have been considered for obtaining an infrared spectrum by transmission. The first method involves the impregnation Cab-o-sil with the nitrate to form a thin disc which is then converted into oxide and the metal itself. Various conditions have been tried to produce a transparent disc which can be placed in a vertical position. Although possible to get transparent discs, none of them has enough strength to sustain breakage during handling. Another method tried involves the use of an evaporated metal film. Using high vacuum (cont.)

1-970. (Cont.)

deposition, a transparent film is placed on the CaF_2 window. A nickel film of 100 angstroms in thickness is transparent to the infrared spectrum. However, the area of the film is relatively small and the amount of chemisorption by propane can be negligible. In view of this limitation, the existing Perkin-Elmer Model 21 requires several modifications to enlarge the sample space and to have the infrared beam moving downward through a salt plate. The impregnation with Cab-o-sil and the subsequent in situ conversion into a metallic catalyst insures an extensive surface area for an observable chemisorption on the spectrum. Since silica is moderately transparent to infrared over wide region of the infrared spectrum, the samples thus prepared might be subject to the wave length limitation.

1-971. FUEL CELL AND ITS RELATED TECHNOLOGY. III. CORRELATION BETWEEN SURFACE CONDUCTIVITY AND CATALYTIC ACTIVITY OF ELECTRODE. Ju Chin Chu and Leonard M. Salzarulo. Final Report, 16 July 1960-15 July 1961. Brooklyn. Polytechnic Inst. Chemical Engineering Dept. 38p. illus. Contract: DA-44-009-ENG-4586. 26 refs. A61-10325.

Surface conductivity and Hall effect are two important indexes for the catalytic activity. For this reason, a program is established to explore the correlation between these properties and catalytic activity of the fuel cell electrode. Conductivity measurement alone gives information about the product of mobility and carrier concentration. Hall effect determines these quantities separately. The so-called Hall coefficient can be evaluated if a current is passed through the materials at right angles to a magnetic field. Equations for the Hall voltage are presented for both cylindrical and rectangular shapes of a sample. For the measurement of Hall effect during chemisorption, a complete setup has been designed. For simplicity in depositing the catalytic film, the cell is made of cylindrical form. The catalyst metal is deposited on the cylindrical surface by vacuum vaporization from a tungsten filament, upon which the catalyst has been attached by electrodeposition. In carrying out the vacuum deposition, the area of axial tungsten filament is made negligible in comparison to the film area.

(cont.)

1-971. (Cont.)

The various types of polarization which occur in a fuel cell are discussed. Among them are activation polarization, mass transport polarization, gas transport polarization and electrolyte concentration polarization. Quantitative expressions are developed for various types of polarizations. The function of a catalyst is to reduce the magnitude in activation polarization. In the light of these quantitative expressions, the factors affecting polarization other than the activation can be kept constant during the operation of a fuel cell. Thus, the effect of various catalysts upon the activation polarization can be explored. Two fuel cells have been designed and fabricated. The first one is made of PVC and the second is constructed of Teflon. The cell contains two stuffing boxes, one in the top flange and one in the bottom of the cell. A sintered alumina tube impregnated with the metal catalyst can be positioned between the stuffing boxes. The change of activation polarization with different catalysts on the electrode can be evaluated in such a cell.

1-972. HIGH ENERGY BATTERIES. Final Report, 15 June 1958-14 June 1961. Eastman Kodak Co. Rochester, N. Y. Apparatus and Optical Div., Lincoln Plant, Rept. no. EK/ARD ED-670. 31 July 1961. 87p. illus. Contract: NOrd-18249. AD 260 700. A61-10335.

An investigation into the feasibility of high energy battery based on the use of the magnesium-sulfur couple in an electrolytic solution in liquid ammonia has shown that it is possible to obtain as much as 50 watt-hrs/lb of cell structure (electrodes, electrolyte, and spacers) at a 15-minute rate. Translation into an automatically activated battery would probably reduce this value to less than 20 watt-hrs/lb. There is little change in output between -40° C and +20° C. The battery could persumably be used at considerably lower and higher temperatures with nearly the same output. Whereas such a battery appears to be competitive with other automatically activated reserve batteries, especially for low-temperature service, it delivers about 7% of the desired output of 250 watt-hrs/lb. Therefore, it is concluded that the feasibility of very high energy batteries has not yet been demonstrated.

1-973. HIGH ENERGY: WEIGHT RATIO, NICKEL CADMIUM CELLS. J. C. Duddy and A. J. Salkind. J. Electrochem. Soc., vol. 108, no. 8, Aug. 1961, p. 717-19.

Conventional nickel cadmium cells contain the active materials in either porous sintered nickel plaques or in nickel or nickel-plated steel pockets or tubes. A new process, adaptable to continuous methods of production, has been developed in which the active and conductive materials are dispersed in a microporous plastic structure. Cells with the high energy to weight ratio of 40 watt-hr/kg have been constructed. Cell volumes are equal to those of the sintered plate design for equivalent capacities.

1-974. INVESTIGATIONS LEADING TO THE DEVELOPMENT OF IMPROVED SEALED NICKEL-CADMIUM BATTERIES. H. N. Seiger. Third Quarterly Progress Report, 1 Jan. 1961-31 Mar. 1961. Gulton Industries, Inc., Metuchen, N. J. Alkaline Battery Div. 45p. illus. Contract: DA-36-039-SC-85390. A61-10312.

Ceramic-to-metal seals are now produced consistently. The equipment for producing seals on the pilot plant level is being placed into operation. Accelerated testing of separator materials has been completed, and the properties of separators are reviewed. The promising separators now require testing in prototype cells. Six new separator materials were received during the last quarter and evaluation started. Overcharge data has been obtained on six cells. The data consists of the capacity, Tafel slope and pressure slope. Several cells with a ratio of negative to positive capacity near unity, were brought into several different states of charge. These cells were then pressured with oxygen and the pressure decrease obtained. This preliminary experiment will be repeated to confirm the data obtained. The question of oxygen adding capacity to a cell was investigated, and a negative answer obtained. The oxygen evolution data was analyzed on a phenomenological basis. The theory of the analysis was developed and is presented in the report. It appears that pure nickel has two sources of

(cont.)

1.974. (Cont.)

oxygen which have half-times of 9 and 102 min respectively. A third self-discharge process is also occuring, but no data has been obtained on this. The doped electrodes have two self-discharge processes which are suspected of being one oxygen source undergoing sequential decay. The potential decay data has been reported as the Tafel slopes.

1-975. INVESTIGATION OF AgO PRIMARY BATTERIES. G. M. Wylie. Seventh Quarterly Progress Report, 1 Jan 1961-31 Mar. 1961. Electric Storage Battery Co. Raleigh, North Carolina. Missile Battery Div., Rept. no. E-11-61. 8 May 1961. 21p. illus. Contract: DA-36-039-SC-78319, Proj. no. 3G18-03-001. AD 258 899. A61-8842.

Non-reserve primary Zn/KOH/AgO cells were assembled and tested in an ESB-type 5-15 size cell to evaluate positive electrodes, negative electrodes, and separator systems. Using the most efficient positive and negative electrodes tested to date and the separator system giving the best 160° F charged stand, sealed cells were assembled and tested in an ESB-type S-7.5 cell container. New cells gave the following discharge results:

Discharge Rate (hrs)	Watt-hrs/lb	Watt-hrs/in.^{3}
5	75	6.35
25	78	6.5
100	84	7.0

Experimental-type 5-15 cells employing a variety of separator systems were stored at 160° F for up to six weeks and then discharged at the 1.5 amp (cont.)

1-975. (Cont.)

continuous rate. With the best separator system tested, the capacity retention after six weeks storage at 160° F was 50%.

1-976. INVESTIGATIVE STUDY RELATING TO FUEL CELLS. Quarterly Report no. 4, 26 Jan.-25 Apr. 1961. California Research Corp., Richmond, Calif. 26 June 1961. 55p. illus. Contract: DA-49-186-502-ORD-929. AD 260 347. A61-10329.

Product studies with methanol in an acid electrolyte fuel cell were continued. More reliable formic acid analyses were obtained. These results show definitely that formaldehyde and formic acid are both intermediates in acid electrolyte but that they are present only in low concentrations. Therefore, these materials are not stable products and are no obstacle in the complete utilization of the methanol fuel in this system. The non-electrochemical disappearance of formaldehyde was studied. Some reactions are suggested to account for the results. These reactions and a known reaction of formic acid produce fuel cell active products, such as hydrogen. Therefore, they need not seriously affect the efficiency obtainable from the methanol cell. Propane fuel cell studies have been resumed. Variables in electrode preparation are being studied first in order to obtain more active reproducible electrodes. The studies of the "cyclic" voltammetric behavior of methanol, formaldehyde, and formic acid or formate have been extended over the pH range of about -1 to 15. Where plots of peak current vs fuel concentration are linear, we postulate that either there is an adsorption step which is rapid (cont.)

1-976. (Cont.)

compared to diffusion or there is a slow adsorption step but surface coverage happens to vary nearly linearly with bulk fuel concentration. When the plots are not linear and tend to flatten out at higher bulk fuel concentration, the adsorption step is probably slower than diffusion and surface coverage is not linear with bulk concentration. Lower peak currents from methanol compared with formaldehyde are consistent with the slow adsorption mechanism. There is evidence that for methanol, formaldehyde, and formic acid, oxidation is catalyzed by acid and platinum oxide. Evidence also exists that the adsorption of an impurity, polymerization product, or strongly adsorbable intermediate can inhibit the oxidation process. The results of our chronopotentiometric study of the anodic oxidation of methanol in basic solution have been re-evaluated. A slow adsorption step involving methylate ion or methanol has been included in the mechanism to explain the data. Other steps in the mechanism remain unchanged. The competitive adsorption of OH^- in strongly basic solution explains the seemingly slower pre-electrode reactions in 8-10 M basic solution. Adsorption processes make it hard to determine accurate values of $(1 - \alpha)n_a$ for the electrochemical step. Best values for $(1 - \alpha)n_a$ lie between 0.3 and 0.4. It is believed that the value of $k_{s,h}$ approaches 10^{-6} cm/sec. Comparisons of anodic reactivity on platinized electrodes of different base metals yield further evidence that vacant d-bands are necessary for the anodic oxidation (cont.)

1-976. (Cont.)

of methanol. Using the same argument, it follows that copper poisons platinum catalyst for this reaction. Chemisorption studies of hydrocarbons on nickel-on-silica have been extended to n-pentane, hexene-1, and isooctane (2, 2, 4-trimethylpentane). It was found that all yield hydrogen atoms on the nickel surface by the process of dissociative adsorption. As a preliminary to studies in the presence of water adsorbed on the metallic surface, 14% of the hydrogen in water was found to interchange with deuterium at 50° C after 1 hr.

1-977. PRELIMINARY PROCESS STUDIES ON THE GENERATION OF HYDROGEN FOR SMALL FUEL CELL SYSTEMS. H. Ozkardes. Kellogg(M. W.) Co., New York, N. Y. Chemical Engineering Div., Rept. no. CE-61-211. 20 Mar. 1961. 62p. illus.
Contract: DA-44-009-ENG-4578. A61-10318.

Alternate generation and purification systems were evaluated to determine the most suitable combination for making pure hydrogen from liquid hydrocarbons to supply small fuel-cell power plants. Preliminary designs were made for 2000 SCFH and 50 SCFH capacity units and thermal efficiencies, weights, volumes and operating requirements determined. An analysis of thermal losses was made for each plant. It was concluded that steam reforming followed by water-gas shift was best suited as a generation system under all circumstances considered in this study but purification methods were greatly influenced by capacity. Feed desulfurization is essential for the 2000 CFH plant requirements but might well be eliminated at the 50 CFH level. The use of a palladium diffuser for obtaining pure hydrogen is highly desirable for the smaller plant and may also be so at the 2000 CFH level. The use of monoethanolamine absorption to remove carbon dioxide followed by conversion of carbon monoxide to methane is practical for the larger plant but not for the smaller. The procedures and controls required for start-up, shut-down and normal plant operation are (cont.)

1-977. (Cont.)

described. Constant operator attendance is required during the first two operations while moderate supervision will suffice during the normal operating period. It is possible to build the 2000 SCFH plant with equipment and knowledge presently available but some development work may be necessary to achieve optimum design. The 50 SCFH unit is completely novel and would require prototype construction and testing.

1-978. REDOX FUEL CELLS. L. G. Austin. Quarterly Progress Report no. 5, 1 Mar.-1 June 1961. Pennsylvania State Univ., University Park. Coll. of Mineral Industries. Dept. of Fuel Technology. 5p. Contract: DA-49-186-502-ORD-917. AD 258 772. A61-8985.

An essential part of a Redox Fuel Cell is the fuel regenerator, where an ion is reduced to a more negative ion by means of a chemical fuel. The problem is to determine, for specified ion pairs and carbonaceous fuels, the volume of fuel regenerator required to maintain current output within the cell. Information on the kinetics of the regeneration process is required, in order to calculate volume versus current requirements at various operating temperatures. Investigations of the reduction of Ti IV to Ti III at temperatures in the region of 200° C have been hampered by the rapid hydrolysis of the titanium ions, giving insoluble TiO_2. Preliminary tests have shown that the Stannous-Stannic system is stable at these temperatures in 4N sulphuric acid. Reactivity tests will be made on this system.

1-979. RESEARCH ON AMMONIA BATTERY SYSTEM. D. J. Doan, G. F. Sieglinger, and E. M. Morse. Third Quarterly Report, 1 Jan.-1 Apr. 1961. Eagle-Picher Co., Joplin, Mo. 92p. Contract: DA-36-039-SC-85396. A61-10311.

The purpose of this contract is to carry on research and development on the use of liquid ammonia as an electrolyte solvent with various cathode and anode materials, towards determining the applicability of the system generally in batteries. The program includes the following investigations: 1) A comprehensive study of possible cathode materials for use with conventional anodes, such as magnesium and zinc immersed in liquid ammonia electrolytic solutions; 2) investigation of liquid ammonia electrolytic systems for optimum performance of new ammonia battery systems, and 3) studies made to establish cell design information best suited to achieve optimum performance throughout the temperature range of -65° F to +160° F. Several mechanical difficulties have been experienced during squib activation of multicell units. Positive plate damage resulting in shorting and high polarization and low capacity was also due to the squib activation. Single cell tests with squib activation indicates that by changing to nylon webril from Aldex separation, to D 4/4-60-90 from D 8/8-30-90 separation and using Plexiglas instead of Polystyrene binder, the plate difficulty may be overcome. Aluminum pits badly on aging at 74° C which precludes its use

(cont.)

1-979. (Cont.)

as reservoir material. Mild steel and 304 Stainless Steel form a film and progressive corrosion stops. Electro-polishing increases the resistance of stainless steel. Several additional cathode active materials have been studied. None have approached present materials for high rate application. Several have possibility for low rate use. A number of parameters have been studied for sulphur as a cathode. 74° C discharge appears to degrade the capacity over -30° C ambient. Coulometric efficiency of 17-20% has been found at -30° C but 9-13% is the best at 74° C. A method of determining ohmic, activation, and diffusion polarizations at any desired current and stage of discharge has been outlined. Initial trials of the method indicate an important ohmic component for the mercury sulphate system. At 74° C, there appears to be an actual self discharge loss, either by chemical reaction or internal shorting, that is, contributing to lower capacity at this ambient where at the -30° C the limitation is due to polarization losses. It seems that the high rate potentialities of this is extremely good over the -50° C to 74° C range and the difficulties outlined above will not seriously jeopardize the application.

1-980. RESEARCH ON LOW TEMPERATURE FUEL CELL SYSTEMS. Progress Report no. 15, 15 Dec. 1960-15 Feb. 1961. General Electric Co. Aircraft Accessory Turbine Dept., Lynn, Mass. 44p. illus. Contract: DA-44-009-ENG-3771. AD 260 739. A61-10330.

The objective of this program is to develop a technology which will serve as the basis for design and fabrication of fuel cell packs for ground power units and power for traction devices for military applications. A primary aim is the more efficient utilization of conventional liquid hydrocarbon fuels. Porous Catalyst Screen Electrodes and Conducting Porous Teflon Electrodes have been employed in a continuing survey of electro-catalyst materials. With this progress report, the survey of metal powders in alkaline electrolyte cells is nearly completed, and some of the trends that have emerged from this phase of the work are discussed. Several compounds have been evaluated as catalyst materials and also some carbon supported catalysts have been prepared and evaluated in cells. In the preceding report, complete electrochemical oxidation of ethylene on a platinum black electrode was observed. The addition of a dehydrogenation catalyst to such an electrode produces some performance on ethane fuel gas at room temperature. It has not yet been determined whether the mechanism of such reaction proceeds by way of dehydrogenation and subsequent (cont.)

1-980. (Cont.)

electrochemical oxidation of ethylene, or whether ethane oxidizes to completion. Work aimed at the characterization of different platinum catalysts has been continued. Coulometric and surface area data have been obtained for additional samples of platinum blacks. A matrix cell having reference electrodes has been constructed and its performance tested with a Kordesch-Marko bridge. In the course of evaluation studies, one alkaline matrix cell was operated briefly on hydrogen and oxygen at current densities as high as 340 ma/cm^2.

SECTION C - MAGNETOHYDRODYNAMIC SYSTEMS

1-981. THE EFFECT OF VARIABLE PLASMA CONDUCTIVITY ON MHD ENERGY CONVERTER PERFORMANCE. W. B. Coe and C. L. Eisen. Trans. Amer. Inst. Elec. Eng.: Pt. II. Appl. & Ind., no. 57, Nov. 1961, p. 225-31. 8 refs.

This paper reports the results of an investigation of the effect of variable plasma conductivity on magnetohydrodynamic energy converter performance. The equations were derived for a constant area channel in which the electrical conductivity of the plasma is dependent on its local thermodynamic properties. There are a number of assumptions in the derivation of equations which include: one-dimensional flow, small magnetic Reynold's number, negligible Hall current, behavior of plasma like a perfect gas, constant specific heats, inviscid and non-heat conducting plasma, electrically neutral, shock-free supersonic flow plasma, and, finally, channel walls which are perfect electrical conductors. The equations were solved numerically, using the IBM 704 digital computer. The performance of energy converters was then plotted and analysed. The following conclusions can be drawn from the results of this analysis: At sufficiently high temperatures (5000 K) the constant conductivity approximation does not introduce serious error in the performance computation. However, at lower temperatures (2000 K) the approximation significantly overestimates the performance. The required entrance flow Mach number for maximum power density (cont.)

1-981. (Cont.)

increases as the entrance stagnation temperature is increased. For the temperature range of immediate interest (2000-5000 K) the required entrance Mach number is always subsonic. In the construction of an actual MHD energy converter, the subsonic Mach number requirement permits more flexibility in the design, and lends more validity to the approximations which are made in the analysis than would be true for a supersonic energy converter. The attainable power density increases sharply with increases in entrance stagnation temperature. Since the maximum temperature that an MHD energy converter can operate at is limited by the capabilities of the materials involved, the reward of large increases in performance for small increases in operating temperatures provides a strong incentive for sophistication in design and for the accomplishment of even small increases in materials capability.

1-982. MAGNETOPHYDRODYNAMICS AND ENERGY CONVERSION. Technical Progress Report No. 2, for period ending 28 Feb. 1961. Massachusetts Inst. of Tech., Cambridge. Research Lab. of Electronics. 15 Mar. 1961. p. 67-88. illus. Contract: AF 33(616)-7624. AD 257 764. A61-8257.

The first part of this report deals with the theoretical studies on electrodynamic and magnetohydrodynamic surface waves and instabilities. A comparison is made here between two simple electrohydrodynamic and magnetohydrodynamic systems involving a surface interaction in plane geometry. The surface dynamics are formulated in terms of the surface traction of Korteweg and Helmholtz. Experimental results are given for two electrohydrodynamic cases. These results indicate that the surface dynamics is strongly dependent on the striction resulting from the interaction, at the molecular level, of the fields with the fluid, and that the effect of electrostriction is considerably less than would be expected from the use of the standard form of the Maxwell stress tensor in conjunction with the Clausius-Mossotti equation. Further, the performance characteristics of cesium thermionic converters are discussed for two types of voltage current characteristics: a) at low cesium pressures where the region of operation is characterized by oscillation in the output region, and b) at cesium

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pressures which are increased to such an extent that the cesium mean-free path is considerably smaller than the interelectrode spacing. Here the sheath type of operation of the cesium converter takes place. The theoretical analysis of this sheath type of operation is presented, considering that the part of the V-I curve in the positive electric power output region is really a part of a sheath curve. It is possible to obtain from a sheath type of V-I curve all of the basic information pertinent to the operation of the cesium converter, provided that the collector work function or the emitter temperature is known.

1-983. MAGNETOHYRODYNAMICS AND ENERGY CONVERSION. Technical Progress Report no. 4, for period ending 31 Aug. 1961. Massachusetts Inst. of Tech., Cambridge. Research Lab. of Electronics. 15 Sept. 1961. 22p. Contract: AF 33(616)-7624. A61-11012.

The purpose of this paper is to report on experiments with a system in which solid conductors are used to traverse a coil and vary the inductance. Such a system should behave like a plasma system except for compressibility effects. The equations for the excitation of the system by a voltage source and for the current yielded by this excitation are derived and used to construct the modified equivalent circuit diagram. In the experiment described in this report the self-excitation was not achieved; however, it is evident from the above mentioned equations and the modified equivalent circuit diagram that the size and character of the conductance G_p can be studied by varying the phase angle of the electrical excitation with respect to the phase of the inductance variation and measuring the impedance. This simple experiment provides a good analytical and experimental basis on which to predict accurately the conditions under which a parametric generator can be self-excited, and to predict the performance characteristics of a self-excited generator. The results obtained are directly applicable to the prediction of self-excitation in the gaseous system and will become in accurate only for (cont.)

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large signals when the gaseous conductor begins to deform appreciably. Further, the experimental study of the oscillations observed in cesium thermionic converters, of the temperature distribution along a strut that is losing heat by conduction and radiation, and the summary on the magnetically driven T-type shock tube of rectangular geometry are briefly presented in this report.

1-984. MAGNETOHYDRODYNAMIC VORTEX POWER GENERATION. W. S. Lewellen. Aerospace Corp., El Segundo, Calif., Rept. no. TDR-594(1203-01)TN-2. 15 Mar. 1961. 35p. illus. Contract: AF 04(647)-594. A61-3555.

The possibility of using a hydrodynamically driven vortex to convert thermal energy into electrical energy is investigated. Two promising areas of application as a space power generator are uncovered. The first is as a short term power supply when used in conjunction with a rocket exhaust and the second is a long term power supply when used in a closed cycle nuclear system. Estimates of the operating characteristics of the MHD vortex in both of these environments are presented. It is concluded that the open cycle MHD vortex should be competitive with other systems for operating times between a few sec and an hr at power levels above a few kilowatts. It is also concluded that replacing the turbo-alternator package in a closed cycle nuclear system with an MHD vortex provides a potential increase in the specific power output (kw/lb) of the order of 100% for power levels above a few hundred kilowatts.

SECTION D - MECHANICAL DEVICES

No entries are made in this issue.

SECTION E - NUCLEAR SOURCES OF ENERGY

No entries are made in this issue.

SECTION F - SOLAR SOURCES OF ENERGY

1-985. CHARGED PARTICLE RADIATION DAMAGE IN SEMICONDUCTORS, I: EXPERIMENTAL PROTON IRRADIATION OF SOLAR CELLS. J. M. Denney and R. G. Downing. Space Technology Labs., Inc., Los Angeles, Rept. no. 8987-0001-RU-000. 15 Sept. 1961. 45p. illus. Contract: NAS5-613. A61-11072.

The effect of proton bombardment on solar cells, particularly silicon, has been experimentally measured at proton energies from 20.5 mev to 740 mev. Comparison of cell type, cell geometry, and parent material, as well as current-voltage characteristics, spectral response, and current decay, with integrated flux at four proton energies is presented. It is found that a relation of the form

$$I_{sc} = I_{sc_o} \left[I - k(\lambda) \log (\Phi/\Phi_k) \right]$$

describes the loss of output of all solar cells under proton bombardment in this energy range. The radiation resistance of shallow diffused oxygen-free p on n silicon cells exceeds conventional cells by a factor of at least five and exceeds n on p cells by a small percentage. The control of radiation resistance by oxygen and other factors is discussed, and the observation of (cont.)

1-985. (Cont.)

annealing in n on p cells at room temperature is noted. Curves summarizing radiation damage rates, for power supply design, are presented.

1-986. 15 KW SOLAR MECHANICAL ENGINE PROGRAM. R. A. Luther. Quarterly Progress Report no. 4, 1 June-1 Sept. 1961. Sundstrand Aviation - Denver, Rept. no. CDRD-61:5011. 51p. illus. Contract: AF 33(616)-7128. A61-10112.

This is the fourth progress report on a contract for development of a 15-kw solar mechanical-engine space vehicle power unit. The power unit is to consist of a 44.5 foot diameter parabolic mirror to collect sunlight, which is focussed in a flux trap secondary concentrator. The solar energy is used to heat the working fluid--liquid rubidium--in a boiler and superheater. The working fluid in the gaseous state operates a turbine which turns an alternator to produce the required electric power. A radiator condenser condenses the rubidium and eliminates the waste heat. The system includes also condensate and cooling pumps, orientation controls and conversion component controls. Pilot models of the parabolic mirror, flux traps, heat receiver and radiator have been fabricated. The Goodyear inflatable mirror has been chosen and contract let for construction of a full-scale mirror. Hardware necessary for the pre-prototype turbine has been ordered and assembly is scheduled for November 1961. The full scale heat storage-boiler component to be tested with the full scale mirror is being designed. Test facilities for the pilot mirrors and for turbine bearing tests are available. Included in the report

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is a section by Goodyear Aircraft Corporation describing progress on the pre-prototype solar collector.

1-987. 4KW SOLAR PHOTOVOLTAIC POWER SYSTEM DESIGN STUDY. R. W. Briggs and A. J. Krause, et al. Bimonthly Progress Report no. 1, 30 Sept. 1961. Westinghouse Electric Corp. Aerospace Electrical Dept., Lima, Ohio. Sept. 1961. 117p. illus. A61-10320.

The objective of this design study is of such scope and magnitude as to allow the preparation of the optimum design for a 4 kw photovoltaic power system for use in an earth orbiting satellite. During the past two months, the following has been accomplished. A foldable assembly of eight frames has been selected for the solar cell array. After reviewing the present and planned booster engines, which might be used for placing an equatorial satellite in orbit, a design criteria was established whereby the array when packaged around a vehicle would fit within a 10-ft diameter nose cone. The analyses of the numerous methods for accomplishing this modular construction is presented within this report. Selected for the design configuration are p on n silicon solar cells since they presently possess the highest energy conversion efficiency and are readily available. Sapphire cover slips have been selected for placement over the solar cells in order to reduce the cell degradation resulting from radiation exposure and particle bombardment. The solar cells will be connected in series--parallel combinations to produce a

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50-watt dc regulated supply. An appropriate number of these 50-watt assemblies can be connected to achieve the required power level. Each 50-watt assembly will contain a dc voltage regulator which will be integrally mounted within the eight-frame array assembly. The power losses within the voltage regulator can thus be directly radiated to space, and no closed loop fluid heat rejection system will be required for the voltage regulators. The design approach results in voltage regulation at the power generation end of the electrical feeders instead of at the dc power bus which is at the power distribution end of the feeders. A study is currently in progress which will analyze the voltage drop, weight, power loss and an arrangement of the electrical feeders. This study will analyze the trade-offs between these items and the weight and number of solar cells within the array. Preliminary analysis of the methods for achieving electrical energy storage have been completed. A continuing review is being performed of the accomplishments in the research and development of solar cells, coatings and cover slips.

1-988. INVESTIGATION OF INTEGRALLY COMPOSED VARIABLE ENERGY GAP PHOTOVOLTAIC SOLAR ENERGY CONVERTER. L. E. Stone and W. E. Medcalf. First Semiannual Technical Report, 9 Feb.-10 July 1961. Eagle-Picher Research Labs., Miami, Okla. Chemical & Metals Div. 10 July 1961. 41p. illus. Contract: DA-36-039-SC-87408. A61-10999.

Gallium phosphide as a discrete phase was produced by the diffusion of phosphorus into gallium arsenide. Diffusion of phosphorus into gallium arsenide powder of 5.2 microns radius under a phosphorus vapor pressure of 20 atmospheres resulted in the formation of a discrete phase of gallium phosphide. Concentration of discrete phase GaP in the diffused powder was determined by x-ray studies to be 82.3%, with GaAs determined as 17.7%. An advantage of variable gap GaP-GaAs cells over single gap GaAs cells is indicated in elevated temperature characteristics, particularly in I_{sc} change. Zinc diffusion by the open tube hydrogen technique offers excellent junction depth control and expedites fabrication over the sealed ampoule techniques. Reliable ohmic contacts to p-type GaAs can be produced by sputtering with platinum followed by coating with solder or baking on silver paste. It is indicated that nonhomogeneity in gallium arsenide single crystals can have a serious negative influence on diode characteristics and conversion efficiencies of solar cells made therefrom.

1-989. SOLAR THERMOELECTRIC PANELS. A. Himle, D. Brush, et al. First Quarterly Report, 1 Nov.1960-31 Jan.1961. General Atomic Div., General Dynamics Corp., San Diego, Calif., Rept. no. GACD-1999. 7p. illus. Contract: AF 33(616)-7676. A61-10332.

A progress report in research and development of solar thermoelectric panels. Improvements must be made in assembly methods and structures of the panels if complexity and fragility are not to become a problem. Replacement of individual elements in the panel has been made possible. Sandwiched foam is being tested and is expected to give the required mechanical strength to the panel. Collector coatings have been tested; the final choice has yet to be made. A thermoelectric contact bonding jig has been built. A high vacuum facility is now in operation for testing components. Thermoelectric elements of n-type lead telluride have been purchased.

SECTION G.- THERMIONIC DEVICES

1-990. NUCLEAR-THERMIONIC POWER UNIT PROPOSED. Barry Miller. Aviation Week, vol. 75, no. 2, 10 July 1961, p. 61-65.

Concept of a compact nuclear-thermionic power supply which does not require moving parts or fluids during its operation and whose design is sufficiently flexible to be tailored to meet different power requirements is being proposed to the Air Force, Atomic Energy Commission and the National Aeronautics and Space Administration by General Electric Co. The powerplant, called STAR (Space Thermionic Auxiliary Reactor), is intended to satisfy the electric power needs of avionic and instrumentation gear of future manned and unmanned space vehicles. The STAR concept envisions a cylindrical power supply comprised of a number of repetitive series-connected rings each containing thermionic diodes, fuel elements and reflectors. Specific power requirements can be satisfied by adding enough rings to produce the desired power.

1-991. OPTIMIZATION OF EMISSION LIMITED THERMIONIC GENERATORS. Alfred Schock. Republic Aviation Corp., Farmingdale, N. Y., Rept. no. PPL-TR-61-3A (259). Feb. 1961. 13p. Contract: NOnr-3285(00). A61-6376.

Equations are derived describing the performance of space charge neutralized thermionic converters with negligible transport effects. For a given anode work function and cathode temperature, optimization of the other system parameters leads to an expression for the maximum attainable conversion efficiency, in terms of the fundamental physical constants e, m, c, and k. The calculated results, presented graphically, suggest several distinct modes of high efficiency operation, and lead to a number of interesting conclusions about converters with cesium coated cathodes.

1-992. A PRELIMINARY EVALUATION OF NUCLEAR THERMOELECTRIC AND THERMIONIC POWER PLANTS FOR SPACE USE. Robert J. Harvey, Fred N. Huffman, and C. Eicheldinger. Martin Co. Nuclear Div., Baltimore, Rept. no. MND-1666. (n. d.) 101p. illus. 32 refs. A61-10333.

This report summarizes the unclassified aspects of a preliminary investigation and conceptual design of a thermoelectric and a thermionic space power supply, utilizing reactor heat sources. A set of ideal specifications has been established as a guide for the investigation of both systems and various reactor types and concepts are considered. Thermal reactors utilizing graphite, beryllium, beryllium oxide, and hydrogeneous moderators are discussed, as well as fast reactors such as molten fuel, uranium dioxide slurry in a liquid metal and uranium carbide-graphite reactors. The uranium carbide-graphite reactor was chosen for both systems. Some of the more important general aspects of the uranium-carbide system are covered; these include fabrication techniques, diffusion of uranium and fission products through the core material, and control of such a reactor. The general design of a space radiator is also discussed. It is shown that for altitudes greater than 100 mi and power densities greater than 1000 Btu/hr-ft^2 a relatively accurate and general radiator design can be achieved considering only the emissivity and temperature of the radiator surface, and the power density (cont.)

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out of the radiator. The thermoelectric power supply is then described. After selecting the material and establishing the hot junction temperature, the ΔT for minimum radiator area was solved for. This condition for the minimum radiator area is far from the optimum operating conditions for the power plant. However, from the vehicle designer's standpoint, minimum radiation area is the optimum situation. Therefore, this condition was used for the remainder of the investigation and conceptual design. During the study it was found that the heat can be best transferred from the reactor heat source to the hot junction of the thermopile by direct radiation. The specific reactor requirements are then established. A conceptual design of a thermoelectric power supply is presented with the problem areas associated with such a plant. For the thermionic power supply, the basic theory of operation of thermionic generators is discussed and the analytic tools for analyzing such a device are derived. A parametric study was conducted to select the proper operating parameters such as anode work function. The heat balance equation was solved to determine the anode temperature. A conceptual design of a thermionic power supply is presented. The restrictions imposed upon the two power supplies due to the assumed specifications are presented. It was concluded that the restriction of no repetitive moving parts or coolant loops did place severe limitations on the thermoelectric design but did not unduly (cont.)

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restrict the thermionic design. However, a thermionic system employing a coolant would have certain additional advantages and could be extrapolated to much higher power levels. The thermionic and thermoelectric designs are compared, and it is shown that ultimately the nuclear thermionic system is more attractive for space applications because of the inherently higher efficiency, smaller radiator area requirements, and reduced susceptibility to radiation damage. However, the thermoelectric system employing a coolant loop is more readily available and therefore, could serve as the transition system to be used until the thermionic system can be made available.

1-993. SEARCH FOR A NUCLEAR THERMIONIC EMITTER.
Paul Stephas. Nucleonics, vol. 19, no. 12, Dec. 1961, p. 66-73.

One of the important problems of developing a thermionic device to convert nuclear heat into electrical energy is finding a suitable thermionic-emitter material to coat the nuclear fuel. For a converter using ionized gas (such as cesium) the emitter material should have a high melting temperature, at least 2000 °C; non-condensable vapor pressure no higher than 10^{-2}mm Hg at operating temperature; evaporation rate low enough to permit long operational life; large thermionic current density; and either low neutron cross-section or the capability to be used as very thin coatings. Of a number of promising materials, the ones that come closest to satisfying all criteria are the carbides and borides of the rare earth and transition metals. Thermionic properties of the promising materials are presented tabularly.

1-994. THERMIONIC CONVERSION OF HEAT TO ELECTRICITY. Nature, vol. 192, no. 4803, 18 Nov. 1961, p. 611-12.

This article is a review of a symposium, held 11 May 1961 in London, organized by the Central Electricity Generating Board (Great Britain) and attended by workers in the field of thermionic generation from a number of public and private concerns in Britain. Most of the papers were concerned with the theory of thermionic power generation. One paper presents an engineering study of thermionic devices for the conversion of nuclear heat to electric power. An experimental model of a cylindrical thermionic diode has been constructed. It uses a rod of uranium carbide-zirconium carbide (25:75) made of depleted or natural material at the end in contact with the tantalum cathode support and enriched material as the fuel at the free end in order to overcome the serious compatibility problem of fuel material in contact with tantalum at 2000 °C.. Other papers discussed the efficiency and power of a diode generator, the work-function of anodes opposite oxide cathodes, the use of the thermionic diode in large-scale power generation, the use of ion injection for space charge neutralization, auxiliary ion sources in cesium diodes, analysis of deionization processes, and crossed field thermionic generators.

1-995. THERMIONIC CONVERTER--DESIGN STATUS AND FORECAST. E. A. Baum and A. O. Jensen. General Electric Co. Power Tube Dept. (n. d.) 14p. 10 refs. A61-10309.

This report covers the performance characteristics of production-type vacuum and vapor thermionic converters. Measurements on sealed-off vapor converters showed much higher power density output and efficiency at lower temperatures (1300 °C) than had previously been thought practical. Lower temperatures usually indicate greater reliability and longer life. Data for arc-mode vapor thermionic converters operating with cathode temperatures of about 1500° C and below are presented. Present materials and techniques create a limit on practical device performance. A power density of about 0.5 watt/cm^2 and an efficiency of about 4% is the maximum achievable today in practical production devices with a reasonable life. A power density of approximately 1 watt/cm^2 and efficiency of approximately 10% at cathode temperatures of 1400° K should be possible from practical closed-spaced vapor devices. A useful life of 1000 to 10,000 hours should be possible for practical sealed-off converter structures operating in the more moderate cathode temperature range of 1500° C and below for space applications.

SECTION H - THERMOELECTRIC MATERIALS

1-996. EFFICIENCY OF THERMOELECTRIC DEVICES. Eric T. B. Gross. Amer. J. Phys., vol. 29, no. 11, Nov. 1961, p. 729-31.

The known expressions for various efficiencies of thermoelectric energy converters can be so modified that the Carnot efficiency of the ideal heat engine cycle appears as one of two significant parameters. The other parameter ZT (Z = figure of merit, T = hot spot temperature in ° K) is a significant characteristic of the thermoelectric material used in the device. For ZT = 1, which is about the best that could be expected of materials for near future space applications, generator efficiencies may range from about 2.6% to 5.3%. For ZT = 2.0, which may be the ultimate maximum it is reasonable now to expect for future materials used in space applications, efficiencies would range from about 4.1% to 8.3%.

1-997. MEASUREMENT OF THE FIGURE OF MERIT OF A THERMOELECTRIC MATERIAL. A. E. Bowley, L. E. J. Cowles, et al.. J. Sci. Instruments, vol. 38, no. 11, Nov. 1961, p. 433-5.

A description is given of a single piece of apparatus for measuring the three parameters involved in the figure of merit of a thermoelectric material. This apparatus uses only direct current and is based on Harman's technique, in which a temperature gradient is established by means of the Peltier effect. It is demonstrated that the corrections for radiative heat transfer take a relatively simple form at room temperature. It is also shown that the figure of merit of a thermoelectric material can be obtained by measuring the maximum lowering of temperature using the Peltier effect in a junction between the sample under test and a metal.

1-998. THERMOELECTRIC MODULE IMPROVEMENT PROGRAM.
Westinghouse Electric Corp., New Products Labs., Cheswick, Pa.
Report no. 1, 1 July 1961. 60p. illus. Contract: NObs-84329.
AD 260 660. A61-10331.

This report summarizes the work in the improvement of thermoelectric modules over the state of the art as expressed by the 5 kw generator type modules and by competing devices. Since many of the attributes of thermoelectric power conversion are well known, this report attempts primarily to define the problems that require solution before thermoelectric generators can be built with the performance characteristics and reliability required for military applications. In addition, a major section is devoted to generator analysis and design for a nuclear reactor-thermoelectric, high heat flux system. A summary of 5 kw generator performance characteristics is as follows: Actual power output 5980 watts gross at a module efficiency of 4.7%. Power output on the basis of best module performance would have been 7570 watts at a module efficiency of 5.7%. Power output on the basis of best thermocouple performance would have been 10,600 watts at 7% efficiency. Life tests on a single couple have exceeded 11,000 hours. Module life was limited to approximately 1000 hours primarily by hot side electrical insulation failure.

1-999. THERMOELECTRICITY APPLICATION CONSIDERATIONS.
A. A. Sorensen. Trans. Amer. Inst. Elec. Eng.: Pt II. Appl. & Ind., no. 57, Nov. 1961, p. 285-9. 11 refs.

The thermopile has both advantages and disadvantages. Compared with other energy-conversion devices, it is simple in construction, with no electrical fluids or extremely close spacings to maintain. Being static, the thermopile has the possibility of long life. It operates from chemical, solar, or nuclear heat sources, is able to use waste heat, and adapts to various ambient conditions. On the other hand, its specific weight is high, voltage is low, and time constants are long. There are numerous semiconducting compounds which will give an electrical output when subjected to a temperature gradient. Some of these are particularly interesting, because, having low thermal conductivity, they are economical in their use of heat. General requirements for practical use of these materials in generators are: high electrical output, low thermal conductivity, stability, and adaptability to production processes. An important phase in any semiconductor materials program is control of the electron or hole concentration in the crystal. The preparation method also effects mechanical characteristics. For example, pressed and sintered lead telluride is machined more readily than cast material. Pressing and sintering also contribute to preparing graded thermoelectric arms; that is, to

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greater doping of the hot end of the arm than the cold end. This is used because the temperature depends on the materials' properties and results in some increase in efficiency. Efficiency is dependent upon the figure of merit (usually designated by Z)--a composite of the Seebeck coefficient, thermal conductivity, and resistivity. Thusfar the highest figures of merit have been attained by materials suitable for use in room-temperature range. Conditions under which design-work operation is to take place must be established--the heat sink temperature, range of temperature from the heat source, required life, and characteristics required by the load. From the standpoint of effect upon the thermopile, designs fall into three general categories: space, terrestrial, and marine. From the designer's viewpoint, space is the worst category because radiation is the only heat-dissipating agent available. For small power applications, conduction may be used to transport heat to the radiator. If the power is appreciable, though, weight becomes excessive for this method, and a circulating fluid system must then be used. When a design is optimized for weight by compromising between the radiator's weight and that of the thermopile and heat source, then the radiator operates at a comparatively high temperature. Optimization may be carried out by analytical solution of equations, by a computer, or by graphical solution based on calculations of several cases.

II. MATERIALS

SECTION A - GENERAL

1-1000. ANALYSIS AND DESIGN OF AN ELECTRON GUN-MOLECULAR BEAM INSTRUMENT FOR USE IN FREE RADICAL STUDIES. Michael P. Charles. Wright Air Development Center. Aeronautical Systems Div., Materials Central, Wright-Patterson AFB, Ohio, WADD TN 60-251. June 1961. 52p. illus. Proj. no. 7360, Task no. 73607. 23 refs. A61-10490.

An electron gun-molecular beam device can be developed and used to study effects of radiation upon materials. Its function is to form a molecular beam with a long free mean path from a known gas. The beam is irradiated by the electron gun producing excited states, ions, and free radicals. Due to length of time from irradiation to being collected on a 4.2° K cold finger, the excited states and ions return to their normal state leaving only free radicals. These deposits are studied at different temperatures by means of infrared and electron paramagnetic techniques. This method promises a reliable history of radiation effect processes which a material will undergo after initial radiation.

1-1001. DEVELOPMENT OF LUBRICANTS FOR POSITIVE-DISPLACEMENT POWER SOURCES FROM 1200° F TO 1500° F. Maurice F. Amateau, Horatio H. Krause, et al. 15 July 1960-14 July 1961. Battelle Memorial Inst., Columbus, Ohio, ASD TR 61-478. 39p. Contract: AF 33(616)-7568, Proj. no. 3044, Task no. 30340. 11 refs. A61-11226.

A program was undertaken to determine the suitability of various materials and lubricants for reciprocating sliding-contact applications to 1500° F in reducing environments. Various possible lubricants were selected for study on the basis of mechanical, chemical, and thermodynamic properties. The most promising of these were exposed to a reducing (nitrogen-hydrogen) environment at 1500° F under 1000-psig gas pressure in order to determine the effects of these conditions on them. On the basis of their properties and experiments, the following materials have been chosen as potential lubricants for use in propellant-driven positive-displacement engines: MoS_2, $MoTe_2$, Ag_2Te, $MoSe_2$, Ag_2S, $PbMoO_4$, $BaSO_4$, lead glass, and Phosphatherm RN. Sliding experiments with various materials lubricated with MoS_2 were performed at 1200° F in reducing and inert environments. No significant differences in the effects of inert or reducing environments on sliding friction or wear were detected.

1-1002. DEVELOPMENT OF 10^7 GYRO SPIN AXIS BEARINGS.
J. T. Luxon, H. S. Kontrovitz, et al. Final Technical Engineering Report, 19 Nov. 1958-19 Feb. 1961. New Departure Div., General Motors Corp., Sandusky, Ohio, ASD TR 61-7-700. Mar. 1961. 219p. illus. Contract: AF 33(600)-38120. 7 refs. A61-11063

This project was initiated to assure the availability of 10^7 gyro spin axis bearings to meet the scheduled requirements of this inertial guidance system. This was to be accomplished by improving the bearing life and capability to reproduce. The program goals of 80% acceptability through a life of 5000 hrs were achieved by an improvement in design details. Functional testing indicates that these bearings may operate successfully in the gyro but final verification was not included in this contract. The modifications in bearing design were restricted to those which retained dimensional compatibility with the present gyro wheel. The basic 10^7 design was altered to incorporate improved separator material, shields, tapered lands and grooved O.D. separators. Bearings of cross forged 52100, low residual 52100, 440C stainless, and M-50 tool steel were built and tested (some tests still running) to determine their effect on life, but no significant improvement in life from the use of other than standard 52100 material can yet be reported. The low residual 52100 bearings had extremely low running torques. Another (cont.)

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approach to increasing life was by altering the internal design to reduce stress without sacrificing angular, radial or axial rigidity. The second major goal of this contract was the development of new manufacturing and gauging techniques and equipment to produce bearings with all critical tolerances held to 20 to 40 microinches. The goal was reached by a method of grinding the O.D., ball race, bore and one face in one machine set up. The part is gauged in process with the instrumentation developed. This reduction of tolerances requires a comparable increase in gauging ability. Improved gauges that were developed included a cross curvature gauge and a roundness gauge using the Link Interference Microscope as a reference. Attempts to produce a test standard to predict bearing life did not yield positive results. Inconsistency of results indicates that the accuracy of preload determined by the current coast down method is questionable. Two different methods were investigated, namely, the yield method and the resonant frequency method. Both are faster than the coast down procedure and have accuracies of 7.5% and 12.5% respectively. This compares with the plus or minus 25% safety factor used with the coast down procedure. A specification has been prepared covering the design modifications and released as a separate document prior to publication of this report.

1-1003. FEASIBILITY STUDY AND DESIGN OF A SELF-ATTENUATING LIGHT VALVE. (Supersedes WADC TR 59-81). John F. Dreyer. Polacoat, Inc., Blue Ash, Ohio, WADD TR 60-827. Feb. 1961. 23p. illus. Contract: AF 33(616)-6715, Proj. no. 7165, Task no. 71839. 14 refs. A61-10554.

The use of phototropic materials as self-attenuating light valves has been re-evaluated in the light of additional information. Sunglass application still appears to be feasible. As eye-protection devices to prevent flashblindness and retinal burns from nuclear detonations, phototropic filters appear to be feasible. However, it is impossible to state that they will provide complete eye protection under all operational conditions until more information is available on: 1) the absorption coefficients of the materials and 2) the tolerance of the human retina to short-duration, high intensity radiation. Phototropy is defined as a phenomenon in which a material not only changes color when exposed to light, but reverts to its original color following removal of the light.

1-1004. FLAME-RESISTANT PARACHUTE PACK MATERIAL. Robert F. Schwenker and Robert K. Zuccarello. Textile Research Inst., Princeton, N. J., ASD Tech. Rept. 61-277. Oct. 1961. 33p. Contract: AF 33(616)-7009, Proj. no. 7320, Task no. 73203. 24 refs. A61-10251.

This work involved the problem of obtaining a flame-resistant parachute pack material that would offer effective thermal protection to the parachute canopy contained therein. During the course of the work, a special apparatus and test method were developed to evaluate fabric heat transmission. Cotton duck fabrics were used as base materials and samples were subjected to 1) chemical modification and 2) resin treatments to improve fabric thermal characteristics. All treatments imparted excellent flame and glow resistance but did not significantly reduce heat transmission through the fabric. However, the combination of a flame- and glow-resistant cotton duck in an adhesive-bonded, two-ply construction, resulted in fabrics of low heat transmission. These two-ply fabrics were found to have the high strength and abrasion resistance required for parachute pack material. The optimum construction that is flame- and glow-resistant and has low heat transmission was achieved by combining THPC-resin-treated cotton duck (12.3 oz./sq. yd.) with untreated cotton poplin (5.5 oz./sq. yd.) into a two-ply fabric using a flame-resistant neoprene formulation as an adhesive. Flammability and heat

(cont.)

1-1004. (Cont.)

transmission tests indicated that this contruction would protect a nylon parachute canopy from any heat damage for at least 10 seconds even while the protecting fabric was attacked by flames having temperatures up to 1400°F.

1-1005. FORMATION OF SILICON SPHERES FOR THE MULTI-ELEMENT LARGE AREA SOLAR CELL. Ilario Massaron and Heinz F. Biekofsky. First Technical Summary Report, 15 Feb. - 14 Aug. 1961. Hoffman Electronics Corp., El Monte, Calif. Semiconductor Div. 81p. illus. Contract: DA-36-039-SC-87420. A61-10247.

Three techniques, called the Horizontal Displacement Furnace (H.D.F.), the Uni-Directional Heater (U.D.H.), and the Vertical Displacement Furnace (V.D.F.), have been devised in order to grow spheroidal silicon crystals suitable for photoelectric application. Apparatus has been constructed and improved, and experimental investigations have been performed in order to evaluate the possibilities and the limitations of the three techniques. The work on the U.D.H. technique was soon discontinued, inasmuch as it seemed unlikely that this method could be mechanized afterwards. It was noticed that the shape and crystallinity of the specimens produced with the V.D.F. technique were consistently better and less affected by modifications in the setup, or variations of the experimental parameters, than the shape and crystallinity of the specimens produced with the H.D.F. technique. It was noticed also that temperature measurements by optical pyrometer were prevented by a progressive darkening of the chambers' walls; that the nature of the refractory material contacting the specimens is rather critical; and that the time (cont.)

1-1005. (Cont.)

the specimen spends in the molten state (mainly depending upon the specimen translational velocity and the susceptor temperature) should be as short as possible. When the experimental parameters are not properly adjusted, either flattening of the specimen or production of appendices will occur. An X-ray study was made to test whether the photomicrographic method, employed to examine the material produced, actually reveals crystallites and grain boundaries. It was found that this method is quite satisfactory within the required accuracy limits.

1-1006. HIGH TEMPERATURE THERMAL CONDUCTIVITY MEASUREMENTS. PART II. THE RECTANGULAR BAR METHOD; EXPERIMENTAL TECHNIQUES. J. N. Pike and J. F. Doar. Union Carbide Corp. Parma Research Lab., and National Carbon Co., Research Lab., Parma, Ohio, Research Rept. no. C-10. 43p. illus. Contract: DA-30-069-ORD-2787. A61-10598, pt. 2.

The report describes the theoretical development of the rectangular bar method of high-temperature thermal conductivity measurements. Corrections for anisotropic materials are derived mathematically. Also rigorously analyzed is the necessity for measurements in a vacuum. The experimental apparatus is described. It consists of controlled electrical devices to heat the sample placed under a bell jar in a vacuum apparatus, and an optical pyrometer to find the apparent black body temperature of the sample. The pyrometer is outside the bell jar and views the sample through a quartz window in the bell jar. Data reduction methods are developed mathematically.

1-1007. A LABORATORY ARC MELTING FURNACE FOR THE PRODUCTION OF ALLOY SAMPLES FROM REACTIVE METALS. John C. Olson. Wright Air Development Center. Aeronautical Systems Div., Materials Central. Wright-Patterson AFB, Ohio, ASD TN-61-32. May 1961. 16p illus. Proj. no. 7371. A61-10488.

An arc melting furnace for the production of small samples of alloys and intermetallic compounds has been designed and built. It is used in phase diagram investigations involving reactive materials such as rare earth metals. It has also been used for the laboratory scale preparation of nickel-copper alloys being studied for magnetic thermometry. In this report, the design, capabilities, and operation of the furnace are described.

1-1008. LIQUID METAL BOILING LITERATURE SURVEY. Richard E. Balzhiser, John A. Clark, et al. Michigan Univ., Ann Arbor. Coll. of Engineering. Preliminary Draft. Sept. 1961. 70p. Contract: AF 33(616)-8277-Item IIa, ORA Proj. no. 04526. A61-10645.

The experimental difficulties associated with a precise evaluation of the effects of many important variables on the heat transfer process in liquid metal media reduce the probability of obtaining directly the needed information. Correlations and studies for nonmetallic fluids are certain to fill the many voids in the liquid metal picture. Therefore, summaries of the present status of boiling heat transfer in general have been included. The authors of this report have attempted to summarize in reasonable detail the results of these investigations. A preliminary compilation of liquid metal properties has been included along with those of water so that interested speculators might assess the applicability of the more general boiling correlations for liquid metal systems. The interrelationship between boiling heat transfer and two-phase flow has also prompted a short summary of the latter. A list of 1108 references is given. It contains articles pertaining to boiling heat transfer, two-phase flow, liquid metal heat transfer, liquid metal circulating systems and related problems, and physical properties of liquid metal media.

1-1009. LIST OF REIC PUBLICATIONS ISSUED. Battelle Memorial Inst. Radiation Effects Information Center, Columbus, Ohio. 4p. A61-10327.

Lists titles of classified and unclassified publications issued by Radiation Effects Information Center up to June 1961.

1-1010. MATERIALS RESEARCH FOR LUBRICANTS AND HEAT TRANSFER FLUIDS. Karl R. Mecklenburg. Midwest Research Inst., Kansas City, Mo., WADD TR 61-259. May 1961. 37p. Contract: AF 33(616)-7336. A61-11220.

A discussion of the design concepts of an apparatus to boil and condense liquid metals, liquid metal salts, and nonmetals is presented along with schematics and drawings. Viscosity, density-temperature, surface tension, and flash, fire, and pour points data for extreme temperature range electronic coolants are presented and discussed. Heat requirements for a high speed bearing apparatus were determined and the necessary modifications were made to extend the operating temperature to 700°F. Greases were studied to determine their life at temperatures from 350°to 450°F. Experimental agreement of the IAE gear lubricant testing machine data is discussed. The design of a vacuum dry film apparatus is discussed along with certain operating features. Results of lubricant studies using the Four-Ball Wear Tester are presented, and the modifications made to extend the operating range of the Four-Ball Wear Tester are discussed.

1-1011. THE PREPARATION OF ALKALI HALIDE PRESSED PELLETS FOR INFRARED ANALYSIS (U). A. M. Bedard and J. L. Myers. Canada. Armament Research and Development Establishment, Valcartier, Que., CARDE Technical Memo 341/60. May 1961. 11p. illus. Contract: PCC no. D46-10-28-19. A61-10185.

A study has been made of the pressed pellet technique for preparing samples for quantitative infrared analysis. A simple, readily available vibratory grinder is described which permits both the rapid grinding to optimum particle size and the homogeneous mixing of the sample with the halide salt. Results with benzoic acid are presented to illustrate the superiority of the method.

1-1012. SILICA MICROBUBBLES. J. W. Lefforge. Emerson & Cuming, Inc., Canton, Mass., WADD TR 60-201, Pt. I. (n.d.). Contract: AF 33(616)-5840, Proj. no. 7340.

Glass microbubbles 0.150 to 0.020 mm diameter, having a bulk density of 0.25 g/cc and a true density of 0.50 g/cc have been greatly improved by decreasing the alkali content and also by making them of vitreous silica. The improvements consist of marked decrease in moisture absorption, enhanced electrical properties, and great increase in maximum use temperature. An acid leaching technique applied to the commerically available 18% alkali "Eccospheres" of Emerson & Cuming, Inc. reduces the alkali content to 6% and increases the maximum use temperature from 500°C to 800°C. Formation from pure silica by a direct high temperature process to give a vitreous silica bubble retains the useful characteristics of the low-melting-alkali-glass bubble with the desirable properties of vitreous silica: i.e., low to negligible moisture absorption, outstanding dielectric properties even at high temperature, and a safe use temperature for most applications of 1300°C. The feasibility of the direct process has been briefly demonstrated on pilot plant scale at 2 lb/hr rate. Work on bonding the high temperature product into structural shapes is described.

SECTION B - HIGH STRENTH METALS

1-1013. FRACTURE TOUGHNESS OF SAE 4340 STEEL HEAT-TREATED TO 200, 000 TO 300, 000 PSI YIELD STRENGTHS. W. W. Gerberich. California Inst. of Tech., Pasadena. Jet Propulsion Lab., Rept. no. 32-96. 15 Apr. 1961. 15p. Contract: NASw-6. A61-6591.

A new heat-treating process known to increase the yield and ultimate tensile strengths was investigated to determine its effect on the fracture toughness of 0.13-in. sheet specimens of SAE 4340 steel. For comparison purposes, a conventional heat treatment which was expected to yield low-energy fracture and a two-step austenitizing process known to decrease notch sensitivity were also investigated. Standard tensile tests showed that the new and two-step heat treatments gave high yield-ultimate strength ratios, while the conventional process gave a much lower ratio. Also, the new heat-treating process, although decreasing over-all elongation, increased local ductility for a particular yield or ultimate strength. How these heat treatments affect the brittle-fracture characteristics was determined with the ASTM recommended center-crack fracture test for sheet materials. Using Irwin's analysis of the modified Griffith theory, the data show that the new and two-step heat treatments increase the fracture toughness over conventional heat treatments. The improvement ranges from approximately 60% at the 200, 000-psi yield-strength level to over 100% at higher levels. For any given ultimate tensile (cont.)

1-1013. (Cont.)

strength, the improvement remains constant at about 45%. A tentative explanation for this increase in fracture toughness considers that raising the yield/ultimate strength ratio increases the local ductility for a particular strength. This results in a larger plastic zone at the crack tip in a fracture-toughness test, which consequently increases toughness. This is somewhat substantiated by correlating fracture toughness to an empirical strength function, (strength ratio)$^{3/2}$ / (yield strength).

1-1014. REVIEW OF CURRENT GOVERNMENT-SPONSORED RESEARCH AND DEVELOPMENT ON SUPERALLOYS. D. E. Price and H. J. Wagner. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Rept. no. S-6. 26 June 1961. 44p. Contract: AF 33(616)-7747. 23 refs. A61-11227.

The results obtained to date from 23 research programs sponsored by the Government since January 1959, which relate to superalloys, are discussed in this report. Included in this report are discussions of four research programs that involve the preparation of experimental alloys and the examination of their properties. In one of these programs, a cast nickel-base alloy has been developed with better stress-rupture properties than those possessed by current commerical alloys. Two programs concerned with the development of wrought cobalt-base alloys have yielded two alloys with stress-rupture properties comparable to those of one of the better commercial wrought cobalt-base alloys. The fourth program is concerned with the dispersion strengthening of a nickel-base matrix with Al_2O_3. This method of preparing alloys for "superalloy" application is still in the early stages of development, and the properties obtained at this time are not yet comparable to those of present-day commercial alloys. A major part of the Government-sponsored research on nickel- and cobalt-base alloys is devoted to providing (cont.)

1-1014. (Cont.)

techniques and basic data which will aid future alloy-development programs. The powder-metallurgical approach to the production of superalloys is being emphasized. Progress is being made, for example, in the development of composite powders containing both the matrix and the dispersed phase for use in the production of superalloys with structural stability and high strength at very high temperatures. The results of a program concerned with the effect of precipitate particle size on the high-temperature strength of nickel-base alloys imply that improved properties may be obtainable in such alloys through improvements in heat-treating procedures. The effect of melting practice on the reproducibility of properties has been investigated, and the results indicate that the impurities obtained from the melting stock, crucible, etc., are more critical than is contamination of the melt by gases. Three programs are concerned with the fabrication of superalloys. In one of these, progress is being made in the production of thin-walled tubing reduced on both ends for use in a hypersonic boost-glide vehicle. In the same program, progress has been made also in methods of manufacturing corrugated wing panels from superalloy sheet. One of the other programs has resulted in the production of René 41 bar from powder with properties comparable to those of conventional wrought René 41. The third fabrication program is concerned with the rolling of flat René 41 sheet to close tolerances. This program is still in the preliminary stages and no conclusive results are yet available.

1-1015. REVIEW OF RECENT DEVELOPMENTS IN THE METALLURGY OF HIGH-STRENGTH STEELS. H. J. Hucek and A. R. Elsea, Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 132. 20 Oct. 1961. 2p. A61-10260.

This report summarizes developments in the metallurgy of high-strength steel between 1 July and 30 September 1961. The effects of austempering of an AISI Type S-5 steel are reported. Austempering of this steel produces better properties at the 220, 000-psi yield-strength level; the benefits are not evident at the higher strength level used.

1-1016. REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF HIGH-STRENGTH STAINLESS STEELS. D. A. Roberts. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 131. 13 Oct. 1961. 3 p. 4 refs. A61-10259.

A new very-high-strength martensitic stainless steel, AFC 77, has been developed by the Crucible Steel Co. of America. It produces tensile strengths of 290, 000 psi at room temperature and 120, 000 psi at 1200°F. Processing was without difficulty. The steel can be welded. International Nickel Company has released data on a martensitic nickel steel. Yield strengths up to 300, 000 psi with good fracture toughness can be produced. Crucible Steel Company has developed wrought modified Fe-Al-Mn-C alloys for intermediate temperature use. The tensile properties compare favorably with the A-286 superalloy, but the stress-rupture strength is inferior. Tensile-strength tests under rapid-heating and constant-temperature conditions on stainless steel sheet have been conducted.

1-1017. REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF NICKEL-BASE AND COBALT-BASE ALLOYS. D. A. Roberts. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 135. 31 Oct. 1961. 2p. A61-10261.

The report includes important developments during the period August to October 1961. Work of interest reported includes dispersion hardening of nickel-base materials and a new approach to the development of high-temperature nickel-base alloy sheet. Also included is previous work on the cracking of jet engine buckets recently declassified.

1-1018. STRESS-CORROSION CRACKING OF HIGH-STRENGTH STAINLESS STEELS IN ATMOSPHERIC ENVIRONMENTS. C. J. Slunder. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Rept, no. 158. 15 Sept. 1961. 38p. illus. Contract: AF 33(616)-7747. 6 refs. A61-10550.

Available information on the stress-corrosion cracking of the high-strength stainless steels is tabulated and discussed. Data are included for austenitic, martensitic, partensitic precipitation-hardenable, and semiaustenitic precipitation-hardenable grades. Although the tests reported are preliminary and further work is in progress, some tentative guidelines are indicated. Stress-corrosion cracking appears to be strongly influenced by prior thermal history.

1-1019. TITANIUM IN AEROSPACE APPLICATIONS. R. I. Jaffee, W. H. Sharp, and R. S. Nycum. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 133. 24 Oct. 1961. 56p. illus. A61-10545.

Titanium was earmarked as a prime material for aircraft from the start, but the initial impetus in research and development of titanium in the United States came from Army Ordnance. However, its potential was recognized by the aeronautical industry, and the major application has been in military aircraft. A significant amount has gone into commercial aircraft, chiefly jet engines, and it is finding increasing application in the aerospace field. Titanium is a relatively high-cost specialty metal whose selection in aeronautical applications over less-costly materials depends on its value in terms of weight savings, longer life, or lower operating cost. The purpose of the present paper is to review the past and current status of titanium in aeronautical applications, including pertinent design criteria, available titanium products and alternative materials, and fabrication problems. Finally, the future possibilities for titanium are considered.

1-1020. TITANIUM DEVELOPMENT PROGRAM. VOLUME I. C. W. Alesch and S. R. Carpenter. Final Technical Engineering Report, Dec. 1957-May 1961. General Dynamics/Convair, San Diego, Calif., ASD Tech. Report 61-7-576. May 1961. Contract: AF 33(600)-34876, ASD Project 7-576. A61-10076, vol. 1.

Ti-4Al-3Mo-1V alloy was selected, in the basic evaluation, over Ti-2.5Al-16V and Ti-6Al-4V because of its greater desirability for satisfying engineering properties requirements, acceptability of mode of heat treatment and over-all manufacturing capabilities for airframe construction employing solution heat treated and aged titanium alloys. Ti-13Cr-11V-3Al was selected, in the supplemental limited evaluation, over Ti-5Al-2.75Cr-1.25Fe due to its superior mechanical property values and spot weld strength values.

1-1021. TITANIUM DEVELOPMENT PROGRAM. VOLUME II. C. W. Alesch and S. R. Carpenter. Final Technical Engineering Report, Dec. 1957-May 1961. General Dynamics/Convair, San Diego, Calif., ASD Tech. Report 61-7-576. May 1961. Contract: AF 33(600)-34876, ASD Proj. no. 7-576. A61-10076, vol. 2.

Detailed incoming inspection data, inspection control chart data, creep test curves and curves comparing properties of various alloys are recorded herein. Interpretative discussions are found in Volume I, ASD TR 61-7-576.

1-1022. TITANIUM DEVELOPMENT PROGRAM. VOLUME III. A. P. Langlois, J. F. Murphy, and E. D. Green. Final Technical Engineering report, Dec. 1957-May 1961. General Dynamics/Convair, San Diego, Calif., ASD Tech. Report 61-7-576. May 1961. Contract: AF 33(600)-34876, ASD Proj. no. 7-576. A61-10076, vol. 3.

Ti-4Al-3Mo-1V alloy was found to be superior to Ti-2.5Al-16V and Ti-6Al-4V considering the over-all forming and joining characteristics determined by the basic fabricability evaluation. In the supplemental evaluation of two additional alloys, the Ti-13V-11Cr-3Al was found to be superior to Ti-5Al-2.5Cr-1.25Fe in mechanical property values and spot weld strength characteristics.

1-1023. TITANIUM DEVELOPMENT PROGRAM. VOLUME IV. A. P. Langlois, J. F. Murphy, and E. D. Green. Final Technical Engineering Report, Dec. 1957-May 1961. General Dynamics/ Convair, San Diego, Calif., ASD Tech. Report 61-7-576. May 1961. Contract: AF 33(600)-34876, ASD Proj. 7-576. A61-10076, vol. 4.

The fabrication of complex parts for both present and future airframe units from the Ti-4Al-3Mo-1V alloy can be achieved with proper design and consideration of alloy forming and joining limitations.

1-1024. TITANIUM DEVELOPMENT PROGRAM. VOLUME V. G. D. Lindeneau, D. H. Love, et al. Final Technical Engineering Report, Dec. 1957-May 1961. General Dynamics/ Convair, San Diego, Calif., ASD Tech. Report 61-7-576. May 1961. Contract: AF 33(600)-34876, ASD Project 7-576. A61-10076, vol. 5.

Typical airframe structures, fuselage frames, wing leading edge, bleed air ducts, tail cone, shear and compression panels of Ti-4Al-3Mo-1V and Ti-13V-11Cr-3Al were subjected to test loads in increases of 100°F from room temperature to maximum temperatures of 800°F and 900°F depending on the part.

SECTION C - REFRACTORY METALS

1-1025. EXTRUSION AND MECHANICAL PROPERTIES OF SOME MOLYBDENUM- AND TUNGSTEN-BASE ALLOYS.
M. Semchyshen and R. Q. Barr. Climax Molybdenum Co. of Michigan, Detroit, ASD TR 61-193. June 1961. 117p. illus. Contract: AF 33(616)-6929, Proj. no. 7351, Task no. 73512. 6 refs. A61-10562.

Successful extrusion techniques have been developed for several molybdenum-base alloys, tungsten-molybdenum binary alloys, and for unalloyed tungsten. Successful extrusions were performed at temperatures from 2000 to 3200°F, and at reduction ratios from 4:1 to 8:1. The use of ceramic (Al_2O_3)-faced extrusion dies was found to reduce the resistance to extrusion and to improve the recovery of sound stock. The problems of die wash and poor bar surfaces associated with high-temperature extrusions through steel dies were circumvented by the ceramic facing. Many of the extruded bars were successfully converted to bar stock by rolling at 2400°F. The degree of success achieved in preparing bar stock from the extruded bars decreased as the amount of tungsten in the alloy increased. Good high-temperature tensile and creep-rupture strengths were displayed by the following alloys: Mo + 1-1/4% Ti + 0.3% Zr + 0.15% C; Mo + 25% W + 0.1% Zr + 0.03% C; Mo + 1-1/2% Cb + 0.5% Ti + 0.3% Zr + 0.3% C. Strengths of binary alloys of tungsten with 10, 30, or 50% molybdenum were below those of the better molybdenum-base alloys at test temperatures of 2400°F and below. (cont.)

1-1025. (Cont.)

It is postulated that the beneficial effects of tungsten-rich refractory alloys would be realized at higher test temperatures. A relationship has been proposed to describe the effect of exposure time on the recrystallization behavior of unalloyed molybdenum, Mo + 0.50% Ti, Mo + 0.059% Zr, and Mo + 0.49% Ti + 0.057% Zr. The effect of externally-applied stresses on the recrystallization behavior of these materials is also treated.

1-1026. INVESTIGATION OF FEASIBILITY OF UTILIZING AVAILABLE HEAT RESISTANT MATERIALS FOR HYPERSONIC LEADING EDGE APPLICATIONS. VOLUME I. SUMMARY. Frank M. Anthony, Fred A. Merrihew, et al. Bell Aerosystems Co., Buffalo, WADC TR 59-744, Vol. I. June 1961. 263p. illus. Contract: AF 33(616)-6034, Proj. nos. 7350 and 1368, Tasks nos. 73500 and 13719. A61-1685, vol. 1.

The purpose of this contract was to investigate the feasibility of utilizing available heat resistant materials in the fabrication of leading edges for hypersonic gliders. This particular volume summarizes the extensive analytical studies conducted from the literature surveys to the testing of the molybdenum alloy and graphite leading edge assemblies produced. By applying proper design philosophies to account for present material limitations it is feasible to produce leading edges for hypersonic gliders by utilizing available materials. In fact, the designs produced appear to be suitable for service use for specific applications. Thus the study demonstrated more than feasibility, it indicated the practicality of immediate utilization of available materials. To avoid possible security problems which might classify this volume, performance capabilities are not summarized. They are presented only in Volume IX. The conclusions of the paper are as follows: 1) It is feasible to utilize available heat resisting materials for hypersonic leading (cont.)

1-1026. (Cont.)

edge applications. Within the scope of potential applications the molybdenum alloy and graphite leading edge assemblies developed may be used for specific service applications. 2) It is possible to use brittle materials for reliable structural components such as leading edges, if proper design philosophies and methods are employed. 3) The major limitation of the most promising presently available materials is the lack of reliable oxidation protection systems. 4) The coated molybdenum alloy leading edge is more reliable than the coated graphite leading edge, both from the standpoint of oxidation resistance and on the basis of tolerance to extraneously induced loadings. 5) The lack of reliability of presently available protective coating systems can be overcome by suitable design procedures. These include the use of large edge radii and a fail-safe design concept with regard to oxidation. The price for reliability is increased weight. 6) Because of the design philosophy employed in this program the coated molybdenum alloy leading edge developed has given every indication of practicality for immediate service utilization on manned reusable hypersonic gliders of up to global range. 7) The graphite leading edge design developed during the study appears to be suitable for unmanned, expendable hypersonic gliders of up to global range. Additional development work is necessary to increase the reliability of the graphite leading edge component to the point where it could be employed on manned reusable gliders.

1-1027. INVESTIGATION OF INTERMETALLIC COMPOUNDS FOR VERY HIGH TEMPERATURE APPLICATIONS. Jonathan Booker, Robert M. Paine, and A. James Stonehouse. Brush Beryllium Co., Cleveland, WADD TR 60-889. Apr. 1961. 143p. illus. Contract: AF 33(616)-6540, Proj. no. 7350, Task no. 73500. A61-11225.

Intermetallic beryllides from the systems tantalum-beryllium, tungsten-beryllium, and hafnium-beryllium along with the disilicides of tungsten, tantalum, and molybdenum, were screened for compounds capable of serving as structural materials at temperatures above 2500°F. The compounds studied were $TaBe_{12}$, Ta_2Be_{17}, Hf_2Be_{21}, $MoSi_2$, and WSi_2. The preparation, fabrication, oxidation resistance, and thermal-shock resistance are discussed. Values are given for the transverse-rupture strengths, impact resistance, mean-linear coefficients of thermal expansion, enthalpy, specific heat, and thermal conductivity. An investigation of the rates of oxidation of intermetallic beryllides was initiated. The oxidation of $TaBe_{12}$, Hf_2Be_{21}, $ZrBe_{13}$, and Ta_2Be_{17} in the range 2300° to 2750°F was found to obey an exponential rate law which was cubic or a higher power rate law. In most cases, the cubic rate law applied. The products of the oxidation of $ZrBe_{13}$ at 2500°F were identified as Zr_2Be_{17} and BeO. Tentative activation energies for a cubic rate process were calculated for $TaBe_{12}$ and Hf_2Be_{21}.

1-1028. INVESTIGATION OF PROPERTIES OF FINE FILAMENTS AND FABRICS OF SUPERALLOYS AND REFRACTORY METALS FOR PARACHUTE APPLICATIONS. Fourth Quarterly Progress Report, 15 Feb.-15 May 1961. Little (Arthur D.) Inc., Cambridge, Mass. 5 June 1961. Contract: AF 33(616)-7294. A61-11217.

During this period all of the room temperature tensile testing was completed for superalloy fine wires exposed to oxidizing atmospheres at 1500-2000°F. The main finding of this work was that all 1/2 mil or 1 mil wires of Elgiloy, René 41, and Inconel 702 were very brittle after 5 minutes exposure to 1800-2000°F. The Elgiloy was the best of the three, having 4-1/2% residual elongation after 5 minutes at 1800°F. The high temperature furnace adapted to our Instron tester was put into use during this period, and tensile properties at 1500-2000°F were determined for 1/2, 1, and 2 mil Elgiloy and René 41. Although for each wire size the Elgiloy had higher room temperature strength, the René 41 gave higher ultimate tensile strength (measured at temperature). However, for both alloys, tensile properties fell off very fast above 1500°F (e.g. 1/2 mil René 41 at RT, 1500°, 1800°, and 2000°F had 208,000, 155,000, 60,000, and 27,000 psi). A study of the apparent modulus of these samples strongly suggests that plastic flow is the predominant factor at 1800-2000°F, suggesting that very short-term creep tests (1-10 minutes) be made on these fine wires. Electro-plating (cont.)

1-1028. (Cont.)

tests to date have not been encouraging, so that current emphasis on finding very thin protective coatings for the molybdenum and tungsten are centered about the vapor plating techniques. Work with di-cumene chromium has progressed to the point of testing some of the plated wires. Attempts to apply a very thin Chromalloy W-2 coating resulted in the same problem as with the electroplating, namely, high porosity with consequent high oxidation rate. The Fabric Research Laboratories, Inc. have successfully down-twisted 7x1, 1/2 mil Chromel V wire and attempts are being made to weave this material into fabrics.

1-1029. INVESTIGATION OF THE PROPERTIES OF TANTALUM AND ITS ALLOYS. Frank F. Schmidt, William D. Klopp, et al. Battelle Memorial Inst., Columbus, Ohio, WADD TR 61-106. May 1961. 154p. illus. Contract: AF 33(616)-5668, Proj. no. 7351, Task no. 73512. 81 refs. A61-10256.

The objective of this research is the development of a tantalum alloy or alloys that can be used in structural applications at temperatures above 1095°C (2000°F). The major immediate applications for tantalum alloys are anticipated as leading edge and structural components in reentry space vehicles. Other applications for tantalum in components for rocket nozzles and control devices also are contemplated. Tantalum has a high melting point (2996°C = 5425°F), excellent room-temperature fabricability, and ductility at subzero temperatures, a combination of properties not found in many refractory metals. Tantalum has only moderate strength properties and poor oxidation resistance at elevated temperatures. However, the high melting point of tantalum and its large capacity for both interstitial and substitutional solutes makes it an attractive base metal for the development of high-temperature alloys. The binary and ternary tantalum-alloy fabricability limits were determined. The limits for binary and ternary combinations fo hafnium, molybdenum, vanadium, and tungsten were extended when fabrication temperature was increased from 980 to 1600°C

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(1800 to 2910°F). It was shown that relatively large amounts of both substitutional and interstitial solutes may be added to tantalum and still maintain reasonable fabricability. Binary alloy additions of columbium, hafnium, molybdenum, rhenium, and tungsten raised the recrystallization temperature of unalloyed tantalum from 1200°C (2190°F) to as high as 1600 and 1650°C (2910 and 3000°F) for the Ta-10Mo and Ta-10W alloys. These binary additions also show the greatest effect in raising the recrystallization temperature in ternary combination. Ternary alloys of Ta-Cb-W, Ta-Hf-W, Ta-Mo-Hf, and Ta-Mo-W have recrystallization temperatures 250 to 500°C (480 to 930°F) higher than those of unalloyed tantalum. All binary and ternary alloys of tantalum exhibited strength improvements over pure tantalum at room temperature. Binary additions of vanadium and hafnium were found to be the most potent strengtheners, increasing the strength from 3600 psi for unalloyed tantalum to as high as 177,600 psi for the Ta-20V alloy. Both dispersion-strengthened and solid-solution strengthened tantalum alloys exhibit high-strength at elevated temperatures while maintaining good fabricability and excellent low-temperature ductility. At 1200°C (2190°F), a four-to-eightfold strengthening improvement over unalloyed tantalum is obtained with binary additions of 5-30% hafnium, 5-10% molybdenum, 5-20% vanadium, 10-20% tungsten, and 1-10% zirconium. Several of the ternary

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alloys tested show strength improvements at 1200°C (2190°F) ranging from six-to-ninefold. Most of the alloys exhibiting high tensile strength at 1200°C (2190°F) show even greater improvements when corrected for density, particularly when the 16.6 g/cm^3 for pure tantalum is considered. Several tantalum alloys exhibited higher strength levels in the temperature range 1000-1690°C (1830-3075°F) as compared with several other refractory metals and alloys. Many of these tantalum alloys also showed excellent strength-to-weight ratios up to at least 1650°C (3000°F). Screening tests were conducted at 1200°C (2190°F) on several binary and a larger number of ternary alloys which were designed primarily for high temperature strength. Small additions of carbon were observed to reduce, by about 15%, the oxidation rates of binary tantalum alloys with titanium, zirconium, or hafnium. Detailed oxidation and contamination studies were conducted on nine complex tantalum-titanium-base alloys which may find application as high-temperature cladding materials. Superior oxidation and contamination resistance were found for Ta-40Ti-10Al and Ta-30Ti-5Al-5Cr. These alloys are about 300 times more oxidation resistant than unalloyed tantalum at 1400°C (2550°F).

1-1030. PHYSICAL METALLURGY OF TUNGSTEN AND TUNGSTEN BASE ALLOYS. Heinz G. Sell, George H. Keith, et al. Westinghouse Electric Corp. Lamp Div., Bloomfield, N. J., WADD TR 60-37, Pt. II. May 1961. 143p. Contract: AF 33(616)-6933, Proj. no. 7351, Task no. 73512. 77 refs. A61-10121, pt. 2.

In continuation of a previous contract AF 33(616)-5632 on tungsten and tungsten base alloys, fundamental properties of high purity tungsten produced both by powder metallurgy techniques and, in the form of single crystals, by electron beam zone melting were studied. High temperature metallurgical properties of several dispersed second-phase tungsten base alloys were also investigated. Additional base line data on the metallurgical properties of pure tungsten for temperatures above 2500°F were also obtained. The mechanism of purification in tungsten during zone melting was studied in order to understand the formation of pores and the effect of pores on growth variables. The flow and fracture characteristics of tungsten single crystal tensiles were investigated as functions of annealing temperature and annealing atmosphere. Internal friction measurements were carried out at 20-800°C on high purity and dosed polycrystalline tungsten wires and single crystals of tungsten. Internal friction damping peaks were tentatively identified to be due to carbon and oxygen. Methods of dosing interstitials into tungsten were further explored. The mechanical properties of dispersed (cont.)

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second-phase tungsten base alloys such as W-ThO_2, W-TaC and W-HfO_2 were studied at temperatures above 2500°F. Previously obtained results on the high temperature strength of the alloys W-ThO_2 and W-TaC were confirmed, and it was found that these alloys retain their margin of strength over that of pure tungsten even at 3000°F. A theoretical investigation of the elastic properties of tungsten and other b.c.c. metals in relationship to the ductile-brittle transition was initiated, and background information was compiled and analyzed.

1-1031. REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF COLUMBIUM AND TANTALUM. E. S. Bartlett and F. F. Schmidt. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 130. 10 Oct. 1961. 4p. 10 refs. A61-10258.

The report includes brief statements about developments in the technology of columbium and tantalum and their alloys between July and September 1961. Tensile properties of a Cb-1Zr alloy at temperatures to 3000°F were published. Two columbium alloys, D-14 and D-36, are commerically available from Du Pont as sheet and strip. Direct forging of cast F48 columbium alloy has been demonstrated. Development of high-temperature, high-strength tantalum alloys is progressing at Battelle and at Crucible.

1-1032. REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF TUNGSTEN. V. D. Barth. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 139. 24 Nov. 1961. 9p. 18 refs. A61-10551.

This memorandum briefly reviews a number of current developments of general interest in the technology of tungsten, and discusses the fabrication of tungsten sheets, extruded tungsten, and single crystals of ultra pure tungsten. Some preliminary mechanical-properties data on three tungsten alloys of current interest are presented in a table form.

1-1033. RESEARCH ON WORKABLE REFRACTORY ALLOYS OF TUNGSTEN, TANTALUM, MOLYBDENUM, AND COLUMBIUM. Crucible Steel Co. of America, Pittsburgh. Central Research Lab., WADD TR 61-134. May 1961. 65p. Contract: AF 33(616)-6172, Proj. no. 7351, Task No. 73512. A61-10257.

This project was undertaken to determine the potential of the tungsten- and tantalum-rich alloys of the W-Ta-Mo-Cb system for high-strength structural applications at temperatures above 2500°F. Twenty specific compositions, including binary, ternary, and quaternary alloys were investigated. Several homogeneous and contamination-free ingots of each alloy were melted by use of a specially designed consumable-electrode vacuum-arc melting unit. Special techniques were developed for the impact extrusion of these alloys, and all alloys were successfully extruded at temperatures from 2500 to 4000°F. Creep and tension tests were conducted on the as-extruded samples at 3000°F in vacuum. The high-temperature strength of the tungsten-rich alloys was increased considerably by the addition of columbium, and the high-temperature strength of the tantalum-rich alloys was appreciably increased by additions of molybdenum and tungsten. One alloy (88.6W-5.7Mo-5.7Cb) had a tensile strength of 62,000 psi at 3000°F; several other alloys had tensile strengths in excess of 50,000 psi. These strengths were attained by a combination of solid-solution strengthening and strain

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hardening. On the basis of results of this investigation, the tungsten- and tantalum-rich alloys of the W-Ta-Mo-Cb system offer excellent promise as wrought materials for structural applications at very high temperatures.

1-1034. STATUS REPORT NO. 1 ON DEPARTMENT OF DEFENSE REFRACTORY METALS SHEET-ROLLING PROGRAM. H. R. Ogden. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Rept. no. 161. 2 Nov. 1961. 31p. illus. Contract: AF 33(616)-7747. A61-10546.

The Department of Defense has established a Refractory Metals Sheet-Rolling Program to accelerate the development of production techniques for high-quality consistent sheet products from the refractory metals and their alloys. The refractory metals being considered for this program are columbium, molybdenum, tantalum, and tungsten which are the metals that have the basic properties needed for many space-age applications. This report summarizes the status of the present contracts on the above program.

1-1035. SUBSTRUCTURE AND MECHANICAL PROPERTIES OF REFRACTORY METALS. B. S. Lement, et al. Manufacturing Labs., Inc., Cambridge, Mass., WADD TR 61-181. Aug. 1961. 255p. illus. Contract: AF 33(616)-6838. 18 refs. A61-11059.

Quantitative results on the substructural characteristics of tungsten, molybdenum, tantalum and columbium are being obtained through the coordinated programs of the five participating laboratories. Changes in subboundary spacing of worked materials have been measured microscopically as a function of annealing temperature, and corresponding changes in particle size and lattice strain have been obtained by Fourier analyses of diffraction-line shapes. Combined application of x-ray reflection microscopy, double-crystal diffractometry, and transmission electron microscopy to single-crystal and polycrystalline tungsten has revealed various orders of substructure in terms of size, disorientation, and dislocation arrays; and progressive alterations have been traced through the stages of recovery and recrystallization. The complex interfolding of the distorted grains and the formation of deformation bands produce an unexpectedly large number of boundary intercepts per unit of transverse distance. There is also a reduction in the amount of grain boundary area transverse to the fiber axis, which probably decreases the

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number of sites for the initiation of brittle fracture. An x-ray technique developed for rapid determination of stereographic pole figures is being applied to a detailed study of the deformation and annealing textures in tungsten strip. Correlations have been found between the substructural characteristics and the mechanical behavior. Recovery-annealing of worked molybdenum strip results in increased ductility which is associated with an increase in x-ray particle size term. Systematic studies on the role of interstitial impurities in tantalum and columbium have been initiated. Measurements of the lower yield stress as a function of grain diameter have confirmed Petch relationships; however, the lattice friction stress was found to be strongly dependent on temperature, impurity content and substructure. Since the substructural detail changes as the annealing temperature is raised to vary the grain size, this may account for the anomalous values of the Petch slope that have been reported previously.

SECTION D.- BERYLLIUM

1-1036. BERYLLIUM CASTING. B. H. Hessler and J. P. Denny. Tenth Interim Technical Report, 5 July-4 Nov. 1961. Phase III. Beryllium Corp., Reading, Penna., Rept. no. AF 33(600)-37902-10. 16p. illus. Contract: AF 33(600)-37902. A61-11060.

Methods have been developed for the production of sound three inch diameter vacuum cast beryllium billets suitable for fabrication. The casting technique relies on a thermal gradient within the mold (hot top, cold bottom) to control directional solidification of the metal and eliminate the centerline shrinkage encountered in convention-alloy cast billets. The thermal gradient casting technique has been found to be reliable and reproducible. Ingots produced by this process show no indication of cracking as determined by radiographic tests and sectioning. Flat beryllium slabs have also been cast using this technique, and these are now being evaluated for soundness.

1-1037. BERYLLIUM OXIDE; A LITERATURE SURVEY. Theodore Cheron. Aerospace Corp., El Segundo, Calif. Literature Research Group, Rept. no. TDR-930(2240-01)TN-1. 1 Sept. 1961. 103p. Contract: AF 04(647)-930. A61-10066.

This bibliography consisting of 283 entries covers the period from 1955 to 1961. The emphasis is on beryllium oxide, its physical, chemical and mechanical properties, preparation and fabrication methods. This is followed by some information on intermetallic compounds of beryllium and certain of its alloys. The third part includes the toxicity of beryllium and beryllium oxide and safety measures. In preparation of this bibliography the open literature sources, pertinent indexes, abstracting journals, unclassified reports, and ASTIA holdings were consulted.

1-1038. DEVELOPMENT OF TECHNIQUES FOR PRODUCING BERYLLIUM STRUCTURAL SHAPES. K. C. Taber and E. E. Weismantel. Third Interim Technical Report, 29 Jan. - 28 Apr. 1961. Final Phase II Report. Beryllium Corp., Reading, Penna., Rept. no. AF 33(600)-41959-3. Contract: AF 33(600)-41959. A61-11373.

This report reviews the technical effort expended in the completion of Phase II of the subject program and includes an evaluation program studying the effects of beryllium oxide level and mill rolling history on the properties of rolled sheet and bar. These studies concluded that the low beryllium oxide product was presently preferred for the development of high strength structural materials because of a better statistical property consistency. In contrast, the higher beryllium oxide material, possessing 5-10% higher ultimate tensile strength at room temperature, had greater deviation in both tensile properties and formability than the lower beryllium oxide material. The testing performed to date has indicated that the ultimate tensile and yield strength objectives of the program will be obtainable using the low beryllium oxide material. Although the flat rolled products only approximated the minimum properties to be attained by the end of the program, the testing of roll-reduced bar resulted in tensile properties as high as 103,800 psi

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ultimate tensile strength, 74,800 psi yield strength, and 6% elongation. Supporting effort expended during this phase has also evaluated processing variables such as specimen preparation, thermal treatments, surface preparation, and the like to determine the effect on mechanical properties. Recommendations are made regarding the projected program to be undertaken in Phase III.

1-1039. THE METALLURGY OF BERYLLIUM. Nuclear Engineering, vol. 6, no. 67, Dec. 1961, p. 531-3.

Under the sponsorship of the Institute of Metals, an International Conference on the Metallurgy of Beryllium was held in London, 16-18 October 1961. Some 70 papers were presented under four main headings--mechanical and physical properties, beryllium in reactors, beryllium in aircraft, and metal preparation and fabrication. This article summarizes the main findings and conclusions described in each session.

1-1040. REVIEW OF RECENT DEVELOPMENTS IN THE TECHNOLOGY OF BERYLLIUM. Webster Hodge. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 138. 16 Nov. 1961. 3p. 8 refs. A61-10544.

A short review of recent developments in the technology of beryllium is given. The refining, purification, joining of beryllium, and corrosion and irradiation behavior of beryllium is discussed.

SECTION E. - COATINGS

1-1041. ANODIC FORMATION OF TITANIUM OXIDE DIELECTRIC FILMS. R. T. Lamoureux. Lockheed Aircraft Corp. Missile Systems Div., Sunnyvale, Calif., Rept. no. 6-90-61-74. Sept. 1961. 14p. A61-10468.

This paper discusses an instrument designed to measure the capacitance and dielectric loss of an anodic film during its formation. It was designed to control the automatic production of capacitors; however, it has become more useful as a tool in studying formation of anodic oxide films. The equipment has been used for continuous measurement of dielectric properties of electrochemically produced titanium oxide films on titanium sheet. Data obtained are discussed in relation to the process parameters of dielectric film formation.

1-1042. APPLICATION AND EVALUATION OF REINFORCED REFRACTORY CERAMIC COATINGS (U). E. W. Blocker. First Quarterly Progress Report, 17 Apr.-31 July 1961. Marquardt Aircraft Co., Van Nuys, Calif., Rept. no. PR 260-1. 15 Aug. 1961. 38p. Contract: AF 33(616)-8209, Proj. no. 1(8-7381), Task no. 73810. A61-10474.

Experimental and commercially available oxidation resistant coatings for tantalum have been applied and evaluated. Test results indicate that protection is afforded to the tantalum reinforcement media. Welding studies indicate the feasibility of spot welding as the attachment means for the reinforcing phase. Chemically formed bodies of zirconia have been produced with a thermal hot face capability in excess of 4000°F. These bodies can be chemically modified to vary the emittance. Techniques of fabricating reinforced, insulating refractory ceramic bodies by the use of vibratory casting have been evaluated.

1-1043. DEVELOPMENT OF A POWDER AND/OR GAS CEMENTATION PROCESS FOR COATING MOLYBDENUM ALLOYS FOR HIGH TEMPERATURE PROTECTION. Herman Blumenthal and Neil Rothman. Chromalloy Corp., W. Nyack, New York, Final Report. July 1961. 77p. Contract: AF 33(616)-7383, Proj. no. 0(7-7381), Task no. 73811. A61-10246.

Prepared W-2 coating on Mo-0.5Ti was found to be essentially $MoSi_2$. Upon exposure at 2700°F the coating becomes three phase and develops an oxidation resistant glaze. A statistically designed experiment was run on two levels of each of nine process variables in order to optimize the W-2 coating process. This experiment indicated that the three most important process variables were time and temperature of processing and mixing of the coating powders. Soundness of the Mo-0.5Ti surface and acid etching of the surface were of secondary importance. Purity, particle size and age of powder mixture and retort material were, statistically, minor in importance. The recommended optimum coating would be produced by processing uncontaminated surface Mo-0.5Ti etched and honed. The work piece should be immersed in a commercial purity, -60 plus 150 mesh powder that is well mixed. The work should be processed twice (12 hours at temperature each time) at 1900°F in a steel retort. The coating produced should have a

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wear life of 47 hrs and a standard deviation of 8 hrs at 2700°F under the oxidation conditions used in this program.

1-1044. HEAT BARRIER COATINGS. Buford A. Macklin, James C. Withers, and Elihu A. Schatz. American Machine and Foundry Co., Alexandria, Va., ASD TR 61-5. July 1961. 72p. illus. Contract: AF 33(616)-7376, Proj. no. 7312, Task no. 73120. A61-10492.

Gold has the lowest emmitance in air at 800°C (0.03) of any material but interdiffuses readily with metallic base materials. A qualitative theory was developed to explain the interdiffusion and allow a prediction of materials to be used as diffusion barrier coatings for gold. Satisfactory diffusion barrier materials investigated were NBS Ceramic A418, NiO, CeO_2, SiO and a variety of phosphate bonded oxides. Nickel oxide and CeO_2 were the best diffusion barrier coatings showing no significant increase in emittance of the gold coating for 110 hours at 800°C. Palladium and rhodium were inferior in many respects to gold as a low-emittance, high-temperature coating.

1-1045. HIGH TEMPERATURE OXIDATION RESISTANT COATINGS FOR TANTALUM BASE ALLOYS. Dean D. Lawthers and L. Sama. Sylvania Electric Products, Inc. Sylcor Div., Bayside, N.Y. ASD Tech. Rept. no. 61-233. (Preprint). SCNC-326. 73p. illus. Contract: AF 33(616)-7462, Proj. no. 7351, Task no. 73512. 5 refs. A61-10116.

Aluminide and beryllide coatings were investigated for pure tantalum, a commercial Ta-10W alloy, and a ternary alloy under development. Coatings were applied by dipping, packing, cold spraying, and vapor deposition. Oxidation resistance was evaluated by furnace testing, resistance heating, and flame testing. Internal hardening and diffusion effects were also studied. A Sn-Al coating was developed, which has excellent oxidation resistance for 10 hrs to at least 3000°F. Evaluation was successfully extended to arc-plasma tests which also showed the feasibility of protecting molybdenum and tungsten. A similar but minor effort investigation was performed with a columbium alloy which could be protected to 2500°F for at least 10 hrs.

SECTION F.- ELECTRIC, ELECTRONIC, AND MAGNETIC MATERIALS

1-1046. ELECTRIC INSULATORS FOR VERY HIGH TEMPERATURES. Monthly Report No. 5, 16 Sept. - 15 Oct. 1961. Illinois Inst. of Tech., Chicago. Armour Research Foundation. 6p. Contract: NAS 8-1547, Proj. no. ARF 6050-7. A61-10819

This report covers work done during the period 16 September to 15 October 1961. The purpose of the study is to develop a solid material which will exhibit maximum resistance to the flow of electricity at the highest possible temperatures, either in a vacuum or in an atmosphere of very low pressure helium or hydrogen, for use in an electric-thermal engine. A secondary purpose is to develop a material with maximum electrical resistance at about 1000°C, in the presence of cesium vapor, for use in an electrostatic engine. During this report period electrical measurements were made on rods of boron nitride, thoria, and beryllia. Additional powdered alumina was prepared by thermal decomposition of aluminum chloride.

1-1047. QUARTERLY PROGRESS REPORT. Scientific Report no. 23, 1 Jan. -31 Mar. 1961. Case Inst. of Tech., Cleveland, Rept. no. AFCRL 380. 27p. Contract AF 19(604)-3887. A61-10822.

Progress is reported on work in the areas of artificial dielectrics with anisotropic properties, surface current measurements, and network synthesis. A polarization diversity lens considered, made from a strip-type artificial dielectric, is discussed. Design equations for the surface contours of this lens are derived. Some theoretical results on probe-reflector interaction, in connection with surface current measurements, are given and discussed. In the network synthesis area an alternate method for arriving at the Bott-Duffin network is introduced. Also a new shorter proof to an extension of Richard's theorem is outlined.

1-1048. SYNTHESIS AND PURIFICATION OF DIELECTRIC MATERIALS. W. C. Divens, D. H. Hogle, et al. Westinghouse Electric Corp., Pittsburgh, WADC TR 59-337, Pt. III. June 1961. 100p. illus. Contract: AF 33(616)-5979, Proj. no. 7371, Task no. 73710. A61-5015.

This is the final report on a contract to synthesize and purify inorganic dielectrics to achieve better dielectric properties at high temperatures up to 500°C. The research program has concentrated particularly on boron nitride and aluminum oxide, with some work on several other materials. During the last year, effort has concentrated on preparing thin films of these materials and evaluating their dielectric properties at high temperature. Thin films of boron nitride and anodically formed alumina have been developed with quite satisfactory dielectric properties at 500°C. Work on arc-plasma jet-sprayed inorganic films starting with high purity materials has yielded only films with inferior dielectric properties, indicating contamination from the arc electrodes.

SECTION G - FABRICATION METHODS

1-1049. FABRICATION OF CUTTING TOOLS BY ELECTROPHORETIC DEPOSITION. M. H. Ortner and K. A. Gebler. Technical Engineering Report, Phase I through Phase IV, 23 May 1960-7 July 1961. Vitro Labs., West Orange, N. J., ASD TR 61-7-868. Oct. 1961. 88p. illus. Contract: AF 33(600)-41436. A61-11064.

The technical feasibility of fabricating carbide coated cutting tools by the electrophoretic deposition process has been demonstrated. Carbide coated lathe tool inserts were prepared which were equal or superior in tool life to commercial, solid, Type-C-6 carbide lathe tools in turning AISI 4340 steel, quenched and tempered to 300 and 500 BHN, at speeds to 200 f.p.m. Carbide coated, 1/4 in. diameter spade drills were produced which yielded a three-fold increase in tool life over an uncoated, type T-15 cobalt HSS drill of the same geometry. The addition of small amounts of boron to the cementing metal proved beneficial in lowering the sintering temperature of grades C-2, C-6, and C-5 carbide coatings on a variety of substrates. A significant feature of these coated tools is the development of a well-defined, hard diffusion zone between the substrate and the carbide coating. This diffusion zone is probably responsible for the excellent bonding achieved throughout the program. Extrapolating from the experimental data, it is reasonable to

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assume that the life of any solid carbide tool can be matched or exceeded in a coated metal tool, and that carbide-coated cutting tools may be fabricated and used in applications where solid carbide tools are excluded because of high cost or excessive brittleness.

1-1050. MACHINING OF SUPERALLOYS AND REFRACTORY METALS. C. T. Olofson and F. W. Boulger. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Memo 134. 27 Oct. 1961. 40p. 65 refs. A61-11065.

Superalloys and the refractory metals are thermally resistant materials capable of maintaining their strengths at high temperatures. This means strengths at temperatures up to 1850°F and 3500°F for the superalloys and refractory metals, respectively. The superalloys described in this report constitute a group of complex nickel-base, cobalt-base, and chromium-nickel-cobalt-iron alloys. The refractory-metals group is less complex and includes molybdenum, tungsten, columbium, tantalum and their alloys. Superalloys and refractory metals are considerably more difficult to machine than ordinary constructional metals and alloys. The low machinability ratings of the superalloys generally result from the tendency of these materials to weld to the cutting edge of the tool. Elements of the refractory-metals group exhibit individual machining problems. This report presents the data available on turning, facing, milling, and drilling operations. It discusses the setups of the above operations, and materials and geometry of cutting and drilling tools as applied to the machining of superalloys and refractory metals.

SECTION H - BEHAVIOR OF MATERIALS

1-1051. BEHAVIOR OF MATERIALS IN SPACE ENVIRONMENTS.
L. D. Jaffe and J. B. Rittenhouse. California Inst. of Tech., Pasadena. Jet Propulsion Lab., Rept. no. 32-150. 1 Nov. 1961. 330 refs. A61-10462.

The quantitative effects of the environments encountered in various regions of space upon several kinds of engineering materials are discussed. In the vacuum of space, magnesium sublimes appreciably at elevated service temperatures; zinc and cadmium sublime at ordinary temperatures. Most other engineering metals will be unaffected by vacuum except for a slight surface roughening. Among the organics, polysulfides, cellulosics, acrylics, polyvinyl chloride, neoprene, and some nylons, polyesters, epoxys, polyurethanes, and alkyds break down at rather low temperatures in vacuum. Polyethylene, polypropylene, most fluorocarbons, and silicone resins do not decompose significantly in vacuum below 250° C. Except for plasticized materials, significant loss of engineering properties in vacuum is unlikely without appreciable accompanying sublimation or decomposition. Also, escape of gases through walls which are gas-tight at 1 atmosphere will not be of concern. For parts intended to move in contact with each other in vacuum, lubrication is a serious problem. Certain low vapor pressure oils and greases, tetrafluoroethylene, and thin films of MoS_2, Au, and Ag can

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probably provide adequate lubrication when suitably selected for the speeds, loads, and times of service. The particles of the Earth's radiation belts will cause radiation damage to organics and to optical properties of inorganic insulators. Semiconductors will be damaged in the inner belt; their more sensitive properties will also be affected by solar flare emissions. Exposed surfaces of most materials may be damaged by the radiation belts and perhaps by solar charged particle emissions. Optical properties of exposed polymers and ceramics will also be affected by solar ultraviolet and X-rays. Sputtering away of material by collision with ions or atoms in space is probably negligible. Erosion by meteoroids is significant only close to the Earth. The probability of penetration by meteoroids falls sharply with increasing distance from Earth. Much more frequent than penetration is spalling of fragments from the inside of walls struck by meteoroids. The efficiency of walls in preventing penetration and spalling can be increased by splitting the walls into a thin front plate and a thicker main plate; quantitative bases for the design of such spaced armor are presented. A bibliography with 330 references is included.

1-1052. DESIGN HANDBOOK FOR O-RINGS AND SIMILAR ELASTIC SEALS. William R. Walker. Boeing Airplane Co., Seattle, WADC TR 59-428, Pt. II. Apr. 1961. 105p. illus. Contract: AF 33(616)-5722, Proj. no. 7381, Task no. 73810. A61-10567.

This is a continuation of the summation of work accomplished under Air Force Contract AF 33(616)-5722, Task no. 73810. It is presented as Part II of a handbook covering the mechanism of O-ring sealing. Data presented herein is concerned with hydraulic and pneumatic systems utilizing static and dynamic type seals at temperatures exceeding 275° F and for static applications at cryogenic temperatures. The effect of vibration, pressure cycling, seal materials and fluids on the operational efficiency of seals and back-up rings are discussed. Sections are devoted to cryogenic, fuel, and vacuum system seals, and to aging and age control. It also includes physical properties of elastomers at high temperatures and a bibliography.

1-1053. THE DESIGN OF PAINT COATINGS FOR SPACECRAFT. L. Whitby. Lockheed Aircraft Corp., Missile Systems Div., Sunnyvale, Calif., Rept. no. LMSD-703026. June 1960. 70p. Contract: AF 04(647)-347. 94 refs. A61-10471.

This report covers the development of coatings for spacecraft. These must withstand vacuum, corpuscular and electromagnetic radiation, hypersonic particulate bombardment of intensities not yet defined, and wide temperature extremes. They must also have optical properties which aid in passive internal temperature control of the satellite. Paint vehicles, pigments and complete systems are discussed in terms of these requirements. It is felt that the inorganic film-formers, such as soluble alkali-metal silicates, polymerized titanium esters, and certain acid phosphates have promise for use as paint vehicles. Some promising reflective pigments are high purity rutile, silicon, and silicon carbide. Optical characteristics of these and other pigments which may be used to control satellite temperatures are presented. A final section discusses the application and optical properties of both unmodified and inorganically-opacified anodic oxide layers on aluminum alloys. Not suggested by the title but apt to be extremely useful are detailed discussions of the spacecraft environment and of the use of emissivity, reflectivity and absorptivity to control temperatures of satellites.

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Parameters of the spacecraft environment considered are solar energy flux, aerodynamic heating, ultraviolet radiation (important in degradation of paints), volatilization in high vacuum, sputtering and micrometeorite erosion, and corpuscular radiation such as cosmic rays, radiation belts and solar winds.

1-1054. EFFECT OF DECARBURIZATION ON NOTCH SENSITIVITY AND FATIGUE-CRACK-PROPAGATION RATES IN 12 MoV STAINLESS-STEEL SHEET. William H. Herrnstein and Arthur J. McEvily. National Aeronautics and Space Administration, Washington, D. C., NASA TN D-966. Nov. 1961. 24p. 9 refs. A61-10038.

Tests were conducted in order to determine the effect of surface decarburization on the notch sensitivity and rate of fatigue crack propagation in 12 MoV stainless-steel sheet at room temperature. Three specimen configurations were utilized in the course of the investigation: standard tensile specimen, 9-in.-wide specimens containing fatigue cracks or thread-cut notches of 0.005-in. radius, and 2-in.-wide specimens containing fatigue cracks. The 12 MoV stainless-steel sheet in the normal condition was found to have an ultimate tensile strength of 251 ksi and to be extremely notch sensitive. The material in the decarburized condition was found to have an ultimate tensile strength of 210 ksi and to be considerably stronger than the normal material in the presence of fatigue cracks. Decarburization did not appear to have any significant influence on the rate of fatigue crack propagation in the 2-in.-wide specimens at the stress levels considered. In addition to the tests, two methods for predicting residual static strength and their application to the material are discussed.

1-1055. EFFECT OF INERT, REDUCING, AND OXIDIZING ATMOSPHERES ON FRICTION AND WEAR OF METALS TO 1000°F. Donald H. Buckley and Robert L. Johnson. National Aeronautics and Space Administration, Washington, D. C., NASA TN D-1103. Oct. 1961. 26p. A61-10049.

Experiments were conducted in inert, reducing, and oxidizing atmospheres to determine their influence on the friction and wear properties of various metals. Nitrogen, argon, forming gas (10 vol. % H_2, 90 vol. % N_2), and various concentrations of oxygen in nitrogen were used. A 3/16-in. radius hemispherical rider under a load of 1000 grams contacted the flat surface of a rotating disk. The surface speed employed was 35 ft/min. The presence of surface oxides is vitally important to the protection of metals in sliding contact. Extremely high friction and excessive wear were encountered in the absence of these oxides. In some instances (electrolytically pure copper), the removal of the surface oxides resulted in mass welding of the specimens in sliding contact. Extremely small quantities of oxygen are sufficient to provide protection of metal surfaces; for example, with 440-C stainless steel, 0.03 vol. % oxygen was found to be adequate.

1-1056. THE EFFECT OF NUCLEAR RADIATION ON STRUCTURAL METALS. Frederic R. Shober. Battelle Memorial Inst. Radiation Effects Information Center, Columbus, Ohio, REIC Rept. no. 20. 15 Sept. 1961. 70p. illus. Contract: AF 33(616)-7375. 85 refs. A61-10635.

The effect of fast-neutron (>1 mev) irradiation on the mechanical properties of structural metals and alloys is somewhat unique in that some properties show changes which are detrimental while others are enhanced by irradiation. Although the yield strengths and ultimate tensile strengths are increased substantially for most materials, the ductility suffers severe decreases. This report presents these changes in properties of several structural metals for a number of neutron exposures within the 1.0×10^{18} to 5.0×10^{21} n cm^{-2} range. Data summarizing these effects on several classes of materials such as carbon steels, low-alloy steels, stainless steels, zirconium-base alloys, nickel-base alloys, aluminum-base alloys, and tantalum are given. Additional data which show the influence of irradiation temperatures and of postirradiation annealing on the radiation-induced property changes are also given and discussed. Increases as great as 175% in yield strength, 100% in ultimate strength, and decreases of 80% in total elongation are reported for fast-neutron exposures as great as 5×10^{21} n cm^{-2}. The ductile-to-brittle

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transition temperature of carbon and low-alloy steels is increased as much as 400° F, for similar exposures. These data are tabulated for individual metals and alloys for easy reference. The Appendix consists of an annotated bibliography of radiation effects publications on structural metals and alloys.

1-1057. THE EFFECT OF SURFACE-ACTIVE AGENTS ON THE MECHANICAL PROPERTIES OF METALS. PART II. THE EFFECT OF SURFACE-ACTIVE AGENTS ON THE MECHANICAL BEHAVIOR OF ALUMINUM SINGLE CRYSTALS. L. R. Kramer. Martin Co., Baltimore, WADD TR 61-58, Pt II. Apr. 1961. 20p. Contract: AF 33(616)-6220, Proj. no. 7023, Task no. 73667. A61-11061, Pt. 2.

Single crystals of aluminum were pulled in tension in a solution of paraffin oil and stearic acid. The critical resolved shear stress for aluminum single crystals does not change as a function of the concentration of the solution. Changes in the extent of strain and slopes of Stages I and II are, however, found to occur and there is an optimum concentration at which the surface-active agent has the largest effect. The fact that the addition of aluminum stearate decreases the weakening effect of stearic acid lends strong evidence that the rate of desorption of the metal soap is the controlling factor governing the effectiveness of the surface-active agent. At low concentrations of the surface-active agent, the rate of desorption is limited by the relatively small number of stearic acid molecules that are adsorbed on the surface of the specimens. At high concentrations, the rate of desorption is limited by the solubility of the metal soap in the solution.

1-1058. ELEVATED TEMPERATURE DYNAMIC ELASTIC MODULI OF VARIOUS METALLIC MATERIALS. W. H. Hill and K. D. Shimmin. Wright Air Development Center. Materials Central. Wright-Patterson AFB, Ohio, WADD TR 60-438. Mar. 1961. 75p. Proj. no. 7351, Task no. 73521. 32 refs. A61-10175.

In the design of load-carrying members subjected to high temperature as well as stress, it is imperative that Young's modulus be known so that deflections can be calculated for any combination of stress and temperature. This property is conventionally determined from the static stress-strain plots of one or several samples tested at each temperature. This widely accepted method has several disadvantages which are discussed more completely later in the report. The principal disadvantage is the large number of carefully prepared specimens needed to establish the temperature dependence of modulus for a given material. Another approach to determination of the elastic modulus (Young's modulus) exists because there is a relationship between the speed of sound in a material and its elastic modulus. Since the speed of sound in a material is manifested in its resonant frequency, it becomes necessary only to determine that property of a material at elevated temperatures to determine the elevated temperature modulus. This determination is obtained nondestructively, thus permitting a large number of determinations at various temperatures from the same sample. The program

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reported here has been conducted for the purpose of evaluating the elevated temperature dynamic modulus of a wide variety of metals and alloys. The special equipment was designed and fabricated for determining the longitudinal resonance of a test sample. In order to provide a comparison of dynamically and statically determined moduli, conventional static modulus tests were performed at room temperature on several materials. The materials considered as representative of those of general interest for elevated temperature structural applications were: Aluminum, beryllium, copper, titanium, iron, cobalt, nickel and refractory alloys. In addition, several pure metals were investigated to provide an indication of the effect upon modulus of alloy additions. Alloys of engineering interest were tested in the condition of heat-treatment considered to be of widest application. Many materials, mostly steels, were tested in both annealed and heat-treated conditions, and the response comparisons are shown graphically. The heat treatment, composition and other pertinent data for each material are given on the data sheet for that material. This investigation demonstrated that the elastic moduli of metals may be determined dynamically at elevated temperatures by using longitudinal resonance (i. e., a relation between the speed of sound in a material and its elastic modules) as a basic parameter. A

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specimen of the material was excited electrostatically and its resonant frequency determined. Knowing the geometry of the specimen, the dynamic elastic modulus was calculated for 40 metals and alloys reported herein. Room temperature comparison of dynamic and static moduli were in most instances using material from the same bar. This simple and straightforward method provided reproducible data which indicate the structural changes taking place in a material. The results of dynamic elastic modulus determinations are graphically presented.

1-1059. EVALUATION OF CERTAIN CRUSHABLE MATERIALS.
D. L. Daigle and J. O. Lonborg. California Inst. of Tech., Pasadena. Jet Propulsion Lab., Tech. Rept. no. 32-120. 13 Jan. 1961. 17p. illus. Contract: NASw-6. A61-10464.

A series of static and dynamic tests of crushable materials, using drop towers and other devices, is described. A crushable material may be used to protect a relatively delicate object at impact by limiting the acceleration applied to the object while absorbing the impact kinetic energy. Materials tested included balsa wood, aluminum honeycomb, and various foam plastics. The tests were not, except in the base of the balsa, extensive, nor was any specific engineering problem under study. The materials were not rated. The intent was rather to develop a guide for the selection of materials for various applications and a method of testing the materials. Details of the instrumentation developed are given in an Appendix.

1-1060. EVALUATION OF BUNA-N (NBR) GASKETS IN PROTOTYPE APPLICATIONS UNDER GAMMA FLUX. John A. Parker and Denver Hale. Wright Air Development Center. Materials Central. Wright-Patterson AFB, Ohio, WADD TR 59-661. Feb. 1961. 34p. illus. Proj. no. 7360, Task no. 73615. 8 refs. A61-10172.

When evaluating and selecting a rubber as a sealant, many environmental factors must be considered beside nuclear radiation. The compounding and curing variations can vary the physical properties and radiation resistance of a particular type of rubber. Both qualitative and quantitative sealability tests were evaluated to verify the theoretical prediction on the stability of certain acrylonitrile-butadiene rubber stock. Although complete data are lacking, it is believed the physical tests on this rubber stock containing ferrocene exhibits radiation stability to warrant additional study. With the exception of peroxide cured stocks, good agreement was obtained between cross-linking efficiency in our first study and the single spot-checked results in this study. There is a linear relationship in the reciprocal of replacement time as determined by the Bopp-Sisman relationship. At the higher doses of 2×10^{10} ergs/g carbon, as given in Figure 16, good agreement between 1/t and flange pressure is required to achieve sealability. An apparatus to determine the

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sealability of gasket materials is described. This apparatus consists of a method of applying a load on the gasket, equipment for pressurizing one side of the gasket seal, and a method of measuring leakage of gas as fluid past the gasket. This report gives a possible method of selecting rubber-like materials for use in a prototype nuclear environment by a calculation of its replacement time from the degree of cross-linking in rubber or polymeric substance. Yet, no one set of rules applies completely in the selection of rubber-like materials for use in aircrafts and missiles.

1-1061. EVALUATION OF STRESSED AND UNSTRESSED MATERIALS IN SIMULATED HIGH ENERGY FUEL EXHAUST PRODUCT ENVIRONMENTS. Joseph W. Rosenbery. Dayton, Ohio Univ., Research Div., WADD TR 60-179. Jan. 1961. 64p. illus. Contract: AF 33(616)-6198, Proj. no. 3048. Task no. 73301. 8 refs. A61-10642.

The effects of corrosion of selected stressed and unstressed high temperature materials by molten boric oxide are presented. A sequence of eleven experimental exposures was accomplished. The effects of small additions of elemental boron and carbon to the molten bath are described. Results show that stress has no significant effect upon the onset or rate of the corrosion process. This report is the last of a sequence of three describing the experimental evaluation of the corrosion of "superalloy" type materials and selected ceramic coatings by boric oxide at temperatures from 1600°F to 2100°F. References: WADC TR 58-443 and WADC TR 59-205.

1-1062. EVAPORATION EFFECTS ON MATERIALS IN SPACE. Leonard D. Jaffe and John B. Rittenhouse. California Inst. of Tech., Pasadena. Jet Propulsion Lab., Tech. Rept. no. 32-161. 30 Oct. 1961. 18p. Contract: NASw-6. 77 refs. A61-10614.

Metals and alloys are generally quite stable in the high vacuum of space at normal operating temperatures. Sublimation of cadmium and zinc may be of some concern, particularly where there is a possibility of the metal plating out in an uncontrolled manner on a cold insulating surface. Sublimation of magnesium and its alloys becomes appreciable above 175°C (350°F). A slight roughening of polished optical surfaces of other metals may occur through selective sublimation. Among the semiconductors, selenium, phosphides, and arsenides have high sublimation or decomposition rates in high vacuum at moderate temperatures. Most inorganic engineering insulators are unaffected by the vacuum of space except at high temperatures. Vapor-pressure and other thermodynamic data are usually available for inorganics of interest, and from these, loss rates can be calculated with good accuracy. In selecting organic materials for use in space, it would be wise either to be conservative, choosing materials known to be safe, or to run tests on doubtful materials. Because of the complex composition of most oil and grease lubricants, simple estimates of their evaporation rates may not

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be reliable. Such polymers as nylon, acrylics, polysulfides, and neoprene show high decomposition rates in vacuum. On the other hand, some commonly used elastomers--vinylidene fluoride-hexafluoropropane, chlorotrifluoroethylene, butadiene-styrene, isoprene, and natural rubber--are rather stable in high vacuum. Similarly, such plastics as silicone resins, tetrafluoroethylene, polyethylene, polypropylene, and ethylene terephthalate exhibit good to excellent behavior in high vacuum. Polymers suitable for high-temperature service are generally best; the use of plasticizers should be avoided.

1-1063. FACTOR OF SAFETY CONSIDERATIONS FOR AERODYNAMICALLY HEATED STRUCTURES SUBJECTED TO HIGH CYCLIC STRESSES. E. H. Nickell and W. E. Jacobsen. Lockheed Missiles and Space Company, Sunnyvale, Calif., ASD Tech. Rept. no. 61-508. Oct. 1961. 95p. illus. Contract: AF 33(616)-8000, Proj. no. 1367, Task no. 136703. 105 refs. A61-10467.

A parametric study has been made from published low-cycle fatigue data showing the various effects on cycles-to-failure. Included are uniaxial and biaxial experimental results. True total strain range, ratio of minimum-to-maximum strain, and effects of geometry are the predominate parameters affecting fatigue life for mechanical cycling at room and elevated temperatures. Structural life was investigated in terms of the parameters for mechanical cyclic loading as well as for cyclic thermal straining. In the former case, expressions relating the parameters to structural life were found. However, in the latter case, no reliable expression between these parameters and structural life was found. A specific expression for conservatively predicting structural life or endurance is developed and applies to all materials, ratios of minimum-to-maximum strains, temperatures, and states of stress. Also considered were single-cycle failures resulting from thermal shock.

1-1064. FATIGUE TEST OF PHENOLIC LAMINATE AT HIGH STRESS LEVELS AND ELEVATED TEMPERATURES. G. H. Stevens. Forest Products Lab., Madison, Wis., Rept. no. 1884. Aug. 1961. 9p. illus. A61-11368.

This report covers fatigue tests made on representative laminates of CTL-91LD resin reinforced with 181-A1100 glass fabric. Fatigue tests with axial loads applied parallel to the warp direction and at zero mean stress were made at the rate of about five cycles per minute. Specimens were tested at room temperature (73° F), 400°, 500°, 600°, and 800°F. All the tests were made on a constant-load type machine and loading was to high stress levels. Starting with the average value found in the static control test, the loads were progressively lowered until a specimen would maintain the established load for about 200 cycles without failure. The specimens, with few exceptions, failed on that portion of the cycle, either in tension or compression, that had the lowest average value in the static control test. Fatigue tests at room temperature showed that at 80 percent of the tension-control strength, specimens would sustain about 200 cycles of repeated loading. At the elevated temperatures, however, there were no clearly indicated trends between 1 and 200 cycles because of strength-time-temperature variations.

1-1065. FOAMED PLASTICS AND OTHER SELECTED INSULATING MATERIALS - A LITERATURE SURVEY. D. F. Green. Naval Civil Engineering Research and Evaluation Lab., Port Hueneme, Calif., Tech. Rept. no. 101. 7 Mar. 1961. 51p. AD 252 981-L. A61-10189.

This report summarizes a literature survey of foamed, thermal insulating materials and recommends future laboratory investigations. It presents information about thermal insulation properties and applications of foamed materials including plastic, rubber, glass, and concrete. Pertinent data from commercial manufacturers' brochures and other available literature is also summarized. Foamed materials have been used extensively for thermal insulation in both the high and low temperature fields, but the survey revealed that, while many proprietary foamed products exist, little information other than that provided by the manufacturers is available about their properties.

1-1066. FORCED VIBRATIONS OF SANDWICH STRUCTURES. A. M. Freudenthal and M. P. Bieniek. Columbia Univ., New York. WADD TR 60-307. Jan. 1961. 30p. Contract: AF 33(616)-7042, Proj. no. 7351, Task no. 73521. A61-8717.

In Part I of this report, a method is presented for the determination of the frequency response functions of the components of deformation and of stress in orthotropic sandwich plates. It applies to the case of simply supported rectangular plates loaded by dynamic pressure normal to their planes. In Part II, a similar method is presented for orthotropic sandwich cylindrical shells. The boundaries of the shell are assumed as simply supported, and the dynamic pressure is normal to the middle surface. In both problems, the analysis takes into account the transverse shear deformation of the core and the material damping of core and facings. The results are presented in the form of expressions suitable for numerical evaluation.

1-1067. HIGH MODULUS, HIGH TEMPERATURE GLASS FIBERS FOR REINFORCED PLASTICS. G. R. Machlan, C. J. Stalego, et al. Owens-Corning Fiberglass Corp., Granville, Ohio, WADD TR 60-24, Supp. 1. Mar. 1961. 230p. illus. Contract: AF 33(616)-5802, Proj. no. 7340, Task no. 73400. A61-10188, Suppl. I.

An exploratory research investigation to determine the feasibility of producing glass fibers which retain useful properties at temperatures up to 2500°F resulted in the development of fibers which had a strength of 110,000 psi at 1800°F, an elastic modulus of 12.8×10^6 psi at room temperature, and a specific gravity of 2.53. A program to improve the strength properties of laminates made from the high modulus glass developed in Supplement I of the contract resulted in laminates which had wet strengths at least equivalent to similar "E" glass laminates and an increase of 34% in wet flexural modulus. A program to develop unidirectional, non-woven, pre-impregnated reinforcement which would produce laminates having very high strength yielded laminates which had a dry flexural strength of 265,000 psi and a dry flexural modulus of 7.81×10^6 psi.

1-1068. HIGH TEMPERATURE RADIATION RESISTANT MATERIALS. C. I. Carr and R. Miller. Progress Report no. 2, 1 Nov. 1960-31 Jan. 1961. United States Rubber Co., Wayne, N. J. Research and Development Dept., Research Center. 15 Feb. 1961. 6p. Contract: NObs 84025. AD 259 107. A61-8840.

An elastomeric material was required capable of resisting limited radiation intensities in the temperature range of 300-600° F. Although adequate unaged physical properties could be obtained using crosslinked linear polyethylene reinforced with carbon black, the compounds embrittled rapidly at 350-450° F using commercial antioxidants. It was found that mixtures of Sb_2O_3 and chlorinated paraffins will protect saturated hydrocarbon polymers such as polyethylene, ethylene propylene copolymer and butyl rubber against the effects of high temperature (300-450° F) oxidation. This report discusses the determining how this system protects, what other polymers will it protect and also what effect the protective system will have upon other types of aging (i. e. in a radiation field, in hot water, and high pressure stream). Oxidation with a model compound indicates antimony oxide and chlorinated paraffins protect materials by altering the path of oxidation. EPR can be protected with Hypalon 40 and antimony sulfide. Polyurethanes cannot be protected by Sb_2O_3 and chlorinated paraffins. Aging of protected polyethylene

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in mild gamma field at 450° F in air causes severe degradation. Steam and water aging of stocks containing Sb_2O_3 and Hypalon absorb sizable amounts of water. Stocks protected with Sb_2O_3 and chlorinated paraffins should not be employed in contact with iron or copper, unless air is precluded from area of contact, because these metals reduce the level of protection.

1-1069. HIGH TEMPERATURE RESISTANT ELASTOMER COMPOUNDS. Leland J. Kitchen, Floyd M. Smith, et al. Firestone Tire and Rubber Co., Akron, Ohio, WADC TR 56-331, Pt. V. Mar. 1961. 137p. illus. Contract: AF 33(616)-6998, Project no. 7340. Task no. 73405. 18 refs. A61-10560, pt. 5.

Compounding studies on heat-resistant elastomers, including acrylate, methacrylate, butyl, chlorosulfonated polyethylene, fluorinated, and silicone rubbers, are described. Viton B and Fluorel 2141 were evaluated and found to have better 400° F physical properties than Viton A or Viton A-HV. HT-1 aromatic polyamide tirecord was evaluated for tenacity at temperatures up to 500° F and found to be far superior to other organic tirecords at high temperatures. Tirecord adhesions of HT-1 tirecord to butyl rubber, methacrylate rubber and Viton A were measured, in comparison with other organic tirecords. The adhesion to resin-cured butyl was brought up to 70 pounds per inch. Eight experimental aircraft tires were constructed from the HT-1 tirecord and resin-cured butyl combination. The adhesions of various heat-resistant elastomers to steel wire tirecord were measured; the best 400° F adhesions were obtained with silicone rubber and methacrylate rubber. Thermal exposure studies, involving four-minutes exposure of elastomer slabs 0.25 inch from a 1000° F metal surface, were continued. Silicone and Viton rubbers performed well. Sponged stocks of the heat-resistant

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elastomers were prepared and evaluated as insulating veneers to protect the slabs from the thermal radiation, but were not effective. Other protective veneers were tested, but none was as effective as a reflective coating of aluminum. Heat-resistant elastomers were oven-aged at 400° F and 500° F for periods up to 500 hours. After 500° F aging, Viton A-HV had the best 73° F tensile properties and SE-555U silicone rubber the best 400° F tensile properties. Polymerization studies included preparation of polyesters from isophthalic acid, and hydrogenation of butadiene copolymers. The most interesting new polymer is a hydrogenated terpolymer of butadiene, styrene and methyl acrylate.

1-1070. IMPACT SENSITIVITY OF METALS (TITANIUM) EXPOSED TO LIQUID NITROGEN TETROXIDE. H. F. Scott, C. W. Alley, et al. Allied Chemical Corp., Hopewell, Va., WADD TR 61-175. May 1961. 27p. Contract: AF 33(616)-7114, Proj no. 7312. Task no. 73122. A61-11224.

The purpose of this investigation was to determine the impact sensitivity of commercially pure titanium, titanium alloy 6Al-4V, and precipitation hardened 15-7 Mo stainless steel when exposed to liquid nitrogen tetroxide. An explanation is given of the probable mechanism of the limited ignition resulting from impact. Commercially pure titanium and titanium 6Al-4V are mildly impact sensitive in liquid N_2O_4. The results are consistent with the theory that N_2O_4 is surface adsorbed on the pure titanium but not on the alloyed titanium. The adsorption process is essentially complete in one day. Commercially pure titanium soaked for 24 hrs in N_2O_4 at 0° C will ignite about 50% of the time if struck with a flat-end pin having an energy of 60-70 ft-lb. Titanium 6Al-4V, soaked or unsoaked, will ignite about 50% of the time if struck with a flat-end pin having an energy of 180-220 ft-lb. Ignition is rarely evidenced by sparks or noise and usually results in small fused areas on the impacted metal surface. Propagation of the reaction does not occur even though sufficient N_2O_4 is present to allow complete oxidation of the metal. The nitrogen evolved from the ignition reaction may slow the

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access of fresh oxidizer and permit time for the diffusion of heat to decrease temperatures below those required to continue vigorous oxidation. Shear, scrape, gall, and high velocity impact data also indicate that titanium is not subject to propagating oxidation in N_2O_4 when impact ignited. The presence of grit on the titanium surface causes a marked decrease in the impact energy required for ignition. This is probably due to the increase in impact energy per unit area around a grit particle and a greater availability of bulk oxidizer at the instant of impact. Precipitation hardened stainless steel, PH 15-7 Mo (Armco condition RH-950) was not impact sensitive in liquid N_2O_4.

1-1071 INELASTIC DESIGN OF LOAD CARRYING MEMBERS. PART I. THEORETICAL AND EXPERIMENTAL ANALYSIS OF CIRCULAR CROSS-SECTION TORSION-TENSION MEMBERS MADE OF MATERIALS THAT CREEP. S. Dharmarajan and O. M. Sidebottom. Illinois. Univ., Urbana. Dept. of Theoretical and Applied Mechanics, WADD TR 60-580, Part I. Jan. 1961. 64p. illus. Contract: AF 33(616)-5658, Proj. no. 7351; Task no. 73521. A61-8724, pt. 1.

This investigation presents a new approach to the problem of multiaxial creep. The theory is based on the usual assumptions; namely, the directions of the principal stresses and strains coincide, the Hencky-Mises flow condition is valid, and the material is incompressible. It is proposed that load-deformation relations be derived for a specified time so that the theory is independent of time. For uniaxial state of stress the flow condition was assumed to be the the isochronous stress strain diagram obtained from constant stress, tension and compression creep curves. The torsion-tension member was chosen to represent the multiaxial states of stress. Sokolovsky's compressible solution was compared with a closed solution based on the assumption of incompressibility. Experimental data were obtained from nylon and polyethylene members tested in a controlled environment room and 17-7PH stainless steel members at 972° F. Good agreement was found between theory and experiment.

1-1072 INELASTIC DESIGN OF LOAD CARRYING MEMBERS. PART II. THE EFFECT OF END CONDITIONS ON THE COLLAPSE LOAD OF COLUMNS. G. A. Costello, O. M. Sidebottom and Eugene Pocs. Illinois. Univ., Urbana, WADD TR 60-580, Pt II. Jan. 1961. 40p. illus. Contract: AF 33(616)-5658, Proj. no. 7351; Task no. 73521. A61-8724, pt. 2.

A theory was presented for constructing the load-deflection relation and for determining the collapse load of a column having any known end condition. A trial and error solution was required which used interaction curves and assumed that the inelastic column assumed the shape of a sine curve. For time independent inelastic deformation, constant depth of yielding interaction curves were used. For time dependent (creep) inelastic deformation are hyperbolic sine interaction curves were used. The experimental part of the investigation included tests of rectangular section columns made of 17-7PH stainless steel and tested at room temperature and at 972° F. Several slenderness ratios were considered, and the columns had end conditions which were either fixed, equal and opposite end eccentricities, or unequal end eccentricities. Good agreement was found between theory and experiment.

1-1073. INELASTIC DESIGN OF LOAD CARRYING MEMBERS. PART III. THE SIGNIFICANCE OF AN INELASTIC ANALYSIS OF ECCENTRICALLY-LOADED MEMBERS. O. M. Sidebottom. Illinois. Univ., Urbana, WADD TR 60-580, Pt. III. Jan. 1961. 23p. illus. Contract: AF 33(616)-5658, Proj. 7351; Task no. 73521. 14 refs. A61-8724, pt. 3.

The author has worked with others on ten investigations, sponsored by Wright Air Development Division, which considered the theoretical and experimental inelastic analyses of eccentrically-loaded tension and compression members. In all cases good agreement was found between theory and experiment for members tested at room temperature and at elevated temperatures. This investigation was undertaken to consider the significance of an inelastic analysis of eccentrically-loaded members. If the inelastic deformation can be considered time independent, a choice has to be made between an elastic and an inelastic solution. A study was made of the effect of several variables on the ratio of the load necessary to produce a specified inelastic deformation to the maximum elastic load. If the inelastic deformation is time dependent (creep), the only choice is an inelastic solution.

1-1074. INVESTIGATION OF CREEP BUCKLING OF COLUMNS AND PLATES. PART III: CREEP BUCKLING EXPERIMENTS WITH COLUMNS OF 2024-0 ALUMINUM ALLOY. Ralph Papirno and George Gerard. New York Univ., New York, WADC TR 59-416, Pt. III. June 1961. 37p. illus. Contract: AF 33(616)-5807, Proj. no. 7381, Task no. 73812. A61-10555, pt. 3.

Experimental data for short time buckling and creep buckling of aluminum alloy 2024-0 columns at 500° F were collected. Two slenderness ratios $L'/p = 40$ and $L'/p = 60$ were tested each with both simulated pinned ends and simulated fixed ends. In addition, compressive short time and compressive creep data for the aluminum alloy material were collected. A technique, whereby end shortening and central deflection data are autographically recorded both during the period when the creep load was being applied and during creep, was used. It was therefore possible to determine initial imperfections by the Southwell method for the creep buckling experiments. Data presented include initial imperfections as well as central deflection and end shortening data. Experimental relationships between applied stress and failure time are presented as well as an analysis of the central deflection and the end shortening data.

1-1075. INVESTIGATION OF FATIGUE BEHAVIOR OF CERTAIN ALLOYS IN THE TEMPERATURE RANGE ROOM TEMPERATURE TO -423°F. Ronald J. Favor, Donald N. Gideon, et al. Battelle Memorial Inst., Columbus, Ohio, WADD TR 61-132. June 1961. 116p. Contract: AF 33(616)-6888, Proj. no. 7351, Task no. 73521. 23 refs. A61-11223.

The fatigue behavior of certain alloys has been investigated in the temperature range room temperature to -423°F. The alloys evaluated are materials currently used for components in cryogenic missile systems. The results of an initial literature search are presented graphically as S-N curves and as fatigue strength-temperature cross plots. In the experimental program, equipment was designed to test small sheet specimens in fully reversed bending, constant maximum deflection experiments at temperatures down to -423°F. Detailed descriptions of the equipment and specimens are presented. Fatigue data obtained on 14 alloys at room temperature, -110°F, -320°F, and -423°F are presented graphically. The metallurgical histories and chemical analyses are described.

1-1076. PRESENTATION OF CREEP DATA FOR DESIGN PURPOSES. M. N. Aarnes and M. M. Tuttle. Boeing Airplane Co., Seattle, ASD TR 61-216. June 1961. 169p. illus. Contract: AF 33(616)-7201, Proj. no. 7381, Task no. 73812. 22 refs. A61-11218.

This program was conducted to obtain additional and comparative creep data, to compare creep data from several sources, and to recommend what values to present and in what form to present creep data for design purposes. Conventional long time creep tests were performed on A-286 at 1200°F and 1500°F; A110AT at 800°F; and Unimach 2 at 600°F and 900°F for purposes of comparing with existing similar data. Conventional creep tests were performed on René 41 at 1250, 1400, 1550, 1700, 1850, and 2000°F. Data were analyzed and are presented in the form of activation series equations. Nomographs were derived for each material. Cyclic creep tests were performed on René 41, in which both stress and temperature were cycled. Cyclic data were found to be comparable to the constant stress constant temperature data.

1-1077. THE PROPERTIES OF COMPRESSION MOLDED, GLASS FLAKE REINFORCED, RESIN COMPOSITES. Albert J. Luirette. Narmco Research and Development Div., San Diego, Calif., Final Summary Report, ASD TR 61-300. June 1961. 167p. illus. Contract: AF 33(616)-7195. A61-11371.

Four molding compositions using glass flake as reinforcement were selected for study by means of a series of screening tests. The physical, electrical and mechanical properties of the compositions after compression molding into flat laminates were determined. Simple geometric shapes such as a hemisphere were compression molded from these compositions. The properties of the simple shapes were compared to the properties of the flat laminates. It was observed that movement of the resin-flake mixture in the molds resulted in very poor alignment of the flakes within the molding. This improper alignment resulted in significantly reduced mechanical properties. It was concluded that this problem is inherent to presently available glass flake reinforced molding compounds and will prohibit the satisfactory compression molding of everything but extremely simple shapes such as flat plates using available molding compounds and molding techniques.

1-1078. RESEARCH ON THE SYNTHESIS OF THERMALLY PROTECTIVE MATERIALS FOR REENTRY ENVIRONMENTS. R. K. Carlson, B. A. Forcht, and D. M. Martin. Chance Vought Aircraft, Inc., Dallas. Sept. 1961. Contract: AF 33(616)-7947, Proj. no. 7340, Task no. 73400. A61-11369.

The primary program objective lies in the experimental synthesis and evaluation of new thermally protective materials for reentry applications. Multicomponent composite systems containing both an ablative filler and a structural substrate phase are currently under investigation. During the report period, porous carbonaceous substrates with "E"-glass, quartz and graphite cloth reinforcement phases were fabricated and impregnated with a large number of organic and inorganic ablative fillers. Plasma arc evaluation of the material composite was initiated at Vought and an ASD contracted facility. Environmental conditions used were: Heat flux, 150 btu/ft^2-sec; Enthalpy, 3000 btu/lb.; Time, 60 seconds. The composites evaluated had in general, a low recession rate (0.001-0.0001 in./sec), excellent thermal stability and fair thermal insulation characteristics. Additional environmental studies under a wide variety of operating conditions will have to be conducted before complete material behavior criteria can be established.

1-1079. STEEL AIRCRAFT CASTINGS. Y. J. Elizondo, C. T. Turner, and W. B. Vorhes. Final Technical Engineering Report, Oct. 1957-June 1961. Chance Vought Aircraft, Inc., Dallas. Aeronautics Div., ASD Tech. Rept. no. 61-7-630. Aug. 1961. 297p. illus. Contract: AF 33(600)-35914, Proj. no. 7-630. A61-10183.

Alloy steels selected for environmental requirements of 600° F and 900° F were modified to permit production of high strength, precision steel castings for aircraft. Strengths on the order of 200,000 psi at room temperature and 170,000 psi at 900° F were obtained with one alloy, and 360,000 psi at room temperature and 245,000 psi at 600° F with a second alloy. The modified alloys were AM-355 and 4340. Casting designs were developed and foundry techniques established to produce three casting configurations utilizing three different foundry processes. Castings were produced and static and fatigue tests were performed to prove the ability to reproduce the mechanical properties obtained during the alloy development phase. Problem areas were found to exist whereby increased process control and inspection requirements were necessary to permit the use of high strength precision steel castings in aircraft designs. Utilizing these increased process controls and inspection criteria, the castings were proven to be feasible as well as competitive with other fabrication processes.

1-1080. THE STIFFNESS PROPERTIES OF STRESSED FABRICS AS OBTAINED FROM MODEL TESTS. George W. Zender and Jerry W. Deaton. National Aeronautics and Space Administration, Washington, D. C., NASA TN D-755. Aug. 1961. 17p. A61-7328

The stiffness properties of a nylon-neoprene fabric material subjected to uniaxial, biaxial, or shear stresses as obtained from tests of simple models are presented. The stiffness properties are applicable to problems involving applied loads after the fabric is in an initial state of biaxial tension such as occurs upon inflation. The results demonstrate the inadequacy of uniaxial tests in obtaining the stiffness properties to be used in the design and analysis of inflatable fabric structures. In order to obtain proper stiffness values for use in the design and analysis of stressed fabric structures, tests of simple models of the type presented herein, subjected to stress conditions similar to those anticipated in the full-scale design, are recommended.

1-1081. STRENGTH PROPERTIES OF REINFORCED PLASTIC LAMINATES AT ELEVATED TEMPERATURES (CTL 37-9X RESIN AND 181-A1100 GLASS FABRIC). Kenneth H. Boller. Forest Products Lab., Madison, Wis., ASD TR 61-482. Oct. 1961. 63p. illus. Contracts: AF 33(616)-58-1 and 61-06, Proj. no. 7340, Task no. 73400. A61-11229.

Several reinforced plastic laminates that show promise of having good strength properties at elevated temperatures are being tested to determine their strength and elastic properties. Flexural, tensile, compressive, interlaminar shear, and bearing tests parallel to the warp direction are made to determine the effects of high temperature and duration of exposure on the strength properties. Tensile tests at 45° to the warp direction are made to obtain data from which edgewise shear strength and modulus of rigidity can be calculated. Creep and stress-rupture data are obtained under both tensile and compressive loads. In addition to strength properties, data are obtained on the weight loss of the laminated material during exposure. This is the fifth of several reports that present strength properties at elevated temperatures. Data on laminated material made of silicone-glass, phenolic-glass, phenolic-asbestos, and epoxy-glass have been presented. This report presents properties of a phenyl-silane laminate made of CTL 37-9X resin and 181-A1100 glass fabric. Data are presented in both tables and curves. In general,

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it is shown that strength properties decrease with increases in temperature. Strength drops with the first application of heat, but at a constant temperature of 300°, 400°, or 500° F the exposed material has a tendency to recover some of that lost strength. Continued exposure above 500° F, however, does not result in recovery of strength. From the curves and data presented here, the effects of temperatures between 80° and 1000° F and exposure periods between 0.05 hr and 1000 hrs on individual strength properties may be judged and interpreted separately. The appendix to this report presents the revised test methods that were used to obtain the data presented here.

1-1082. SURFACE AND ENVIRONMENTAL EFFECTS ON CERAMIC MATERIALS. P. Gibbs, G. S. Baker, et al. Utah. Univ., Salt Lake City. Physics Dept., ASD TR 61-182. July 1961. 27p. Contract: AF 33(616)-6832, Proj. no. 7350, Task no. 73500. A61-10548.

Polycrystalline sintered compacts of doped Alucer MC alumina have been deformed in three point beam loading in the temperature range 1000° to 1350°C. The steady state creep rate of specimens doped with MgO or $Mn(CO_3)_2$ from 50ppm to 5000ppm by weight were fit to the expression A exp (-E/kT). The activation energy E was found to be 130 Kcal/Mole independent of added impurity. The constant A was independent of $Mn(CO_3)_2$, but decreased by a factor of 3-5 on the addition of MgO. It is suggested that polycrystalline creep is controlled by diffusion of vacancies in the steady state. Creep behavior of Linde corundum 0.1 inch diameter rods in three point loading (1000°-1250°C) is described. At the lowest temperatures and stresses studied, measurable creep (0.1μ per hour beam deflection) began after about an hour's time delay, and increased at an accelerating rate. One run was successfully continued to reach a steady state (7500μ deflection). Activation energies increased as creep proceeded (71-135 Kcal/Mole). No mechanical effect could be attributed to flame polishing the samples. A study is described of the dispersal of impurities from a metal contact over the free

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surface of corundum at 10^{-4} mm Hg, by measuring the current flowing between two vacuum deposited films as a function of time, temperature (20-640°C), and applied field (0-12v.). At a given temperature, the current increases linearly with time. Heating to 640°C may increase the room temperature current by 4 orders of magnitude, although the current decreases with decreasing temperature. It is suggested that detaching Ag from the deposited film controls the rate of formation of a semiconducing bridge on or just beneath the corundum free surface.

1-1083. TENSILE AND COMPRESSIVE STRENGTH OF REINFORCED PLASTIC LAMINATES AFTER RAPID HEATING. Kenneth H. Boller. Forest Products Lab., Madison, Wis., WADD TR 60-804. Feb. 1961. 30p. illus. Contract: DO 33(616)-58-1. A61-10559.

Several reinforced plastic laminates that show promise of having good strength properties at elevated temperatures are being investigated to evaluate their strength over their useful range of temperature and duration of exposure. This report, the fifth of several reports that are planned as part of this work, presents the results of tension and compression tests of three plastic laminates after exposure to temperatures ranging from room temperature to 1000° F. and soak periods ranging from about 2 min to 1000 hrs. The data presented for soak periods of 1/2 hr and less were obtained by rapidly heating the specimens (time to heat about 60 sec) with plate heaters in contact with the specimen. Data are also presented for specimens heated in an oven for 1/2 hr and more. Results show the effect of the two methods of heating, plate heat and oven heat. The results of the tests show that the strength decreases immediately with application of heat. Further exposure at constant temperature, however, usually results in an increase in strength. But continued exposure at the higher temperatures eventually results in complete loss in strength. The degree of degradation is a function of the

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kind of material and the temperature and period of exposure. Hence, each material should be judged separately. Matched groups of different materials were tested in tension and compression after exposure of 1/2 hr to plate heat or oven heat. In general, the method of heating did not significantly affect the strength.

1-1084. THE THEORETICAL BEHAVIOR OF KNITTED FABRIC SUBJECTED TO BIAXIAL STRESSES. Peter Popper. Wright Air Development Center. Materials Central. Wright-Patterson AFB, Ohio., WADD TR 60-897. July 1961. 27p. illus. Proj. no. 7320, Task no. 73203. A61-10491.

In this report the theoretical mechanical behavior of a plain knitted fabric subjected to biaxial stresses is derived. An approximate mathematical model of the fabric structure has been established from which the stress vs. fabric-geometry and stress vs. strain relationships have been determined. The work was done by considering only the properties of the fabric structure, completely independent of the fiber properties. The results of this report may be used for such applications as predicting the performance of a plain knitted fabric in situations where it will be stressed biaxially.

1-1085. THERMAL IRRADIATION OF PLASTIC MATERIALS. Herbert S. Schwartz and Rex W. Farmer. Aeronautical Systems Div., Wright-Patterson AFB, Ohio, WADD TR 60-647. Aug. 1961. 71p. Proj. no. 7340. 28 refs. A61-10401.

Degradation and short time rupture of several reinforced plastics and structural adhesives were investigated during intense radiant heating. Thermal response was found to be a function of certain materials properties, stress conditions and environmental parameters. Plastic specimens were preloaded in tension and irradiated in an arc-imaging furnace. Time to rupture was found to be a function of: resin and reinforcement type, spectral characteristics and thickness of the material, angle and magnitude of the applied static stress, and radiant flux density. Rupture times ranging from 0.5 to 45 sec were observed for applied stresses of 20-70% of the ultimate room temperature strength and radiant flux densities of 1-25 Cal/cm^2-sec. An exploratory study was made on an adhesive bonded clad aluminum lap joint loaded in shear and irradiated at 25 Cal/cm^2-sec. Rupture times of 1-10 sec were obtained for static loads of 30-70% of ultimate room temperature strength.

1-1086. THERMAL RADIATIVE CONTROL SURFACES FOR SPACECRAFT. Roger E. Gaumer and Louis A. McKellar. Lockheed Aircraft Corp. Missiles and Space Div., Sunnyvale, Calif., Rept. no. LMSD-704014. Mar. 1961. 63p. illus. Contracts: AF 04(647)-563, AF 04(647)-564, and AF 04(647)-558. 40 refs. A61-4303.

This report summarizes the basic problems of spacecraft thermal control, delineates current problem areas and reviews the experimental and development work directed toward solution of these problems. Measurement of radiation characteristics, determination of the effects of the environment on radiation characteristics of the surfaces of interest, and present state of programs to develop stable surface materials for spacecraft use are discussed. Radiation characteristics of approximately 1000 specimens have been measured in the past six months. The inherent superiority of calorimetric determinations of total emittance over optical determination has become clear. Reflectance measurements are expecially unsatisfactory as a basis for emittance determinations of highly reflectant materials. A device presently under development shows promise of providing direct, rapid, calorimetric determinations of both emittance and α_s/ϵ ratio. This should provide an accuracy of 5-10% as compared to the 50-100% error presently

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incurred in measurements of emittance when $\epsilon < 0.1$. There are major problems of manufacturing and quality control, handling techniques, and surface protection concerning the production of thermal control surfaces. These problems are intensified in the case of large satellites. It is mandatory that thermal control surfaces be treated as the optical surfaces they actually are if reliable operation is to be obtained. Simulated environmental tests have resulted in the tentative approval of several surface materials and in the discarding of many others. Organic paints, in general, are undesirable for spacecraft use because of instability during ascent and in orbit. Both solar ultraviolet radiation and penetrating space radiation types have deleterious effects. A few organic materials have been approved for use in restricted applications. The inorganic paint development program is progressing favorably; it is hoped that a solar reflector with stability for exposure to the space environment for a year will be developed. Several adequate flat absorbers have been found. Surfaces approximating the ideal flat reflector (polished highly reflective metals) and solar absorber (Tabor-type selective radiator) are available. Investigations show promise of leading to self-thermostatic surface-covering materials which, if practical, will provide a superior technique for spacecraft thermal control. The elements of the

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spacecraft environment most harmful to thermal control surfaces are ascent heating, ultraviolet radiation, penetrating space radiation, and for some materials, extreme high vacuum. For the special case of surfaces entering a planetary atmosphere, the entry environment is most severe. Orbital sputtering does not appear to be a significant problem for mission lifetimes of one year. A major obstacle to the achievement of reliable thermal control is the lack of definition of the space environment itself. Uncertainty exists as to the kinetic or quantum energy spectra and spatial distribution of micrometeorites, Van Allen radiation, and solar protons. The earth's albedo, earth emission, and the ultraviolet component of solar radiation require further evaluation. The report contains an excellent bibliography of material available on the various fields pertinent to spacecraft thermal control. Appendices present specific design information and reference data including radiation characteristics of many materials used in spacecraft design. A list of agencies and companies working in these fields is included.

1-1087. THERMO-ELASTIC EQUATIONS FOR A SANDWICH PANEL UNDER ARBITRARY TEMPERATURE DISTRIBUTION, TRANSVERSE LOAD AND EDGE COMPRESSION. Ibrahim K. Ebcioglu. Aeronautical Systems Div., Wright-Patterson AFB, Ohio, ASD TR 61-128. Aug. 1961. 65p. Proj. no. 7351, Task no. 73521. 7 refs. A61-11062.

The problem of designing sandwich panels for use under an arbitrary temperature distribution, transverse load, and edge compression has been extremely simplified. The core of the sandwich panel is assumed to be orthotropic and the faces may be of different thicknesses and materials. The general differential equations for a sandwich panel are obtained from the principles of mechanics, and corresponding boundary conditions are formulated from the principle of virtual displacements and variational calculus. A reduction from five differential equations for a sandwich panel to two independent systems of differential equations is accomplished by the suitable transformations of the independent variables. The final two systems of differential equations are solved simultaneously for an arbitrary temperature distribution, transverse load, and uniform edge compression with simply-supported boundary conditions. The analysis is greatly simplified by the use of the superposition principle. The theoretical solution is applied to a particular temperature distribution and center deflection in the sandwich panel plotted against loading parameter.

1-1088. WEATHERING OF GLASS-FABRIC-BASE PLASTIC LAMINATES UNDER STRESS. Kenneth E. Kimball. Forest Products Lab., Madison, Wis., ASD TR 61-145. June 1961. 28p. illus. Contracts: AF 33(616)58-1 and 33(616)61-06, Proj. no. 7340. A61-11228.

The effect of weathering on the mechanical properties of a reinforced plastic panel while under stress has been questioned for some time. Three different laminates were exposed in the stressed and nonstressed condition for periods up to 3 years, some in Florida and others while stored under normal conditions. After 3, 12, and 36 months, tensile, compressive, and flexural strength properties were determined. Weathering usually had about the same effect on strength properties of stressed panels as on those of nonstressed ones. Laminates exposed to normal conditions generally maintained their original strength during 3 years of exposure. Outdoor exposure at Florida usually resulted in substantial erosion of the surface resin and a loss in strength. Strength losses at the Florida site were often between 15-25%, with some up to 40%. Outdoor weathering in Florida resulted in a greater reduction in strength properties of the polyester laminate than those of the epoxy or phenolic laminates.

SECTION I - WELDING AND BRAZING

1-1089. DEVELOPMENT OF PARTIALLY VOLATILE BRAZING FILLER ALLOYS FOR HIGH-TEMPERATURE APPLICATION AND RESISTANCE TO OXIDATION. PART II. N. Bredzs, J. F. Rudy, and H. Schwartzbart. Illinois Inst. of Tech., Chicago. Armour Research Foundation, WADD TR 59-404, Pt. II. June 1961. 53p. illus. Contract: AF 33(616)-6882, Proj. no. 7351, Task no. 73516. A61-10557, pt. 2

The mechanical properties and the resistance to oxidation of 304 stainless steel joints brazed with the following four experimental filler alloys, containing volatile constituents, have been determined: Alloy A: 61% Ni-39% In; Alloy C: 65% Ni-17% Cr-9% In-9% Si; Alloy I: 33% Ni-33% Cr-17% In-17% Ge; Alloy N: 35% Ni-24% Cr-26% In-15% Ge. A special brazing technique was developed for brazing these joints. The special technique involved: 1) a method of preparation of the alloy so that a homogeneous and desired composition was available to fill the joint capillary and 2) a method of volatilizing the melting point depressant which avoided the difficulty of "boiling", while still obtaining sufficient volatilization to provide the required higher remelt temperature and good high-temperature properties. Miller-Peaslee type specimens brazed by this technique were used for the determination of joint strength at room temperature and elevated temperatures up to 1900° F. The highest shear strength of all four alloys was exhibited by the 65% Ni-17% Cr-9% In-9% Si alloy. The oxidation resistance of all

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joints brazed with the four experimental filler alloys was excellent. Some of the joints brazed with the 61% Ni-39% In alloy showed considerable signs of oxidation after exposure to the open air for 500 hrs at 1600° F.

1-1090. GAS-PRESSURE BONDING. S. J. Paprocki, E. S. Hodge, and P. J. Gripshover. Battelle Memorial Inst. Defense Metals Information Center, Columbus, Ohio, DMIC Rept. no. 159. 25 Sept. 1961. 41p. illus. Contract: AF 33(616)-7747. 36 refs. A61-10263.

Solid-state-bonding techniques are becoming increasingly important with the advent of the space age. A review of the literature on one such technique, gas-pressure bonding, has been made. This report has been prepared to assist the defense industry in evaluating its proper area of usefulness in the over-all joining field. The gas-pressure-bonding process employs a gas at high pressure and elevated temperature in order to fabricate metallic or ceramic materials. The process has been used to produce metallurgical bonds between similar and dissimilar metals, ceramics, and cermet materials. It appears to be ideal for fabricating brittle materials or materials of widely differing properties. Consolidation of metallic and ceramic powders to densities approaching theoretical is readily accomplished by gas-pressure bonding at temperatures well below those normally required in sintering operations. An important result of these low temperatures is that the resulting grain growth is held to a minimum. Numerous configurations have been fabricated from such materials as beryllium and columbium by the gas-pressure-bonding process. Examples are cited of typical nuclear

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fuel elements and various structural components of interest for aircraft and missile application. Bonding parameters are included to familiarize the reader with the general temperatures and pressures being employed.

SECTION J - CHEMICAL AND PHYSICAL PROPERTIES OF MATERIALS

1-1091. DETERMINATION OF THE RELATIONS BETWEEN STRUCTURE AND RADIATION STABILITY OF ARYL ETHER FLUIDS. George E. Bohner, Josef J. Schmidt-Collerus, and James H. Weber. Denver. Univ. Denver Research Inst., WADD TR 60-282, Pt. II. July 1961. 87p. illus. Contract: AF 33(616)-7220, Proj. no. 098-7021, Task no. 73655. 65 refs. A61-10254, Pt. 2.

Aryl ethers are quite resistant to radiolytic degradation. The principal physical property change observed as the result of radiolysis is a rather rapid increase in viscosity. Chemically, weakly acidic and relatively low-boiling compounds are formed. Aryl ethers such as bis [m-(m-phenoxy-phenoxyl)phenyl] ether, m-bis(m-phenoxyphenoxy)benzene and Monsanto DS 124 are more stable toward radiolytic degradation than diphenyl ether or di-phenoxybenzenes if the formation of benzene and phenol is used as a criterion for radiation stability. If, however, the change in viscosity is a measure of stability, then all of these ethers possess the same magnitude of stability. The radiolytic degradation mechanisms of diphenyl ether were studied extensively. These mechanisms involve polymerization reactions and scission reactions of the carbon-oxygen bond of the ether with the formation of phenyl and phenoxy-free radicals. The reaction of these free radicals with

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diphenyl ether explain most of the chemical changes observed. The reaction of the phenyl radical at the ortho position of the diphenyl ether results in the formation of phenol; however, a small amount of this radical forms benzene. The remainder of the phenyl radicals appear to react at the meta and para positions of the ether molecule to form biphenyl phenyl ethers. The mode of the phenoxy radical reactions is less clear; however, they appear to react with diphenyl ether to form isomeric diphenoxybenzenes. The rate of disappearance of diphenyl ether decreases as the radiation dose is increased and becomes nearly constant ($-G_m$ = 0.4-0.5) at high doses. The ether consumed to form polymer increases as the radiation dose is increased and appears to become constant at high doses. The polymeric material is a glassy brown solid with a rather high molecular weight.

1-1092. DIELECTRIC RELAXATION IN HYDROGEN-BONDED LIQUIDS. Matthew W. Sagal. Massachusetts Inst. of Tech., Cambridge. Lab for Insulation Research, Technical Rept. no. 166. Oct. 1961. 23p. A61-10478.

The temperature dependence of the dielectric relaxation time has been investigated from -5° to 50° C for ethanol-cyclohexane solutions from 1.0 to 0.25 mole fraction ethanol. The previously observed maximum in the relaxation time around equimolar composition is explained by a hydrogen-bonded switching mechanism. Measurements of dielectric relaxation from 5° to 50° C have been carried out on three isomeric butanediols which differ in the separation of the two OH groups along the carbon skeleton. The differences in relaxation times among the three isomers can be explained by the switching mechanism suggested by the results for the ethanol-cyclohexane solutions. The dielectric relaxation times of n-butanol from 5° to 50° C have also been determined. The chain-length dependence of the dielectric relaxation time of the normal aliphatic alcohols is discussed in terms of the proposed mechanism.

1-1093. EFFECT OF FLUORINE ON THE CARBONYL STRETCHING FREQUENCY OF ESTERS. Jack Radell and L. A. Harrah. Wright Air Development Center. Aeronautical Systems Div., Wright-Patterson AFB, Ohio, ASD TR 61-110. May 1961. 8p. illus. Proj. no. 7360, Task no. 73607. A61-10547.

The carbonyl stretching frequencies of 19 esters of perfluorinated normal acids and 17 esters of partially fluorinated normal alcohols were measured with a precision of 0.5cm^{-1}. The carbonyl stretching frequencies of the fluorinated esters were found to be consistently higher than the carbonyl stretching frequencies of the corresponding unfluorinated esters and dependent on the amount and position of the fluorine substituents. The behavior of the carbonyl stretching frequency as a function of fluorine position and number can be generalized with the following equation for the acid moiety:

$$V_{c=o} = V_o + 15\, n_{\alpha} + 4.07\, n_{\beta} + 1.88\, n_{\gamma} + 0.8\, n_{\delta} \qquad (1)$$

where V_o is the carbonyl stretching frequency of the unfluorinated ester and n_{α}, n_{β}, etc., are the numbers of the fluorines on the α, β, etc., carbons in the acid segment. The carbonyl stretching frequencies in the esters with

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fluorine substitution in the alkyl segment is given by:

$$V_{C=O} = V_O + 7.97n_\beta, + 1.78n_\gamma, + 1.83n_\delta, + n_\epsilon, \quad (2)$$

where $V_{C=O}$ has its previous significance and n_β', n_γ', etc. are the number of fluorines on the α, β, etc. carbons of the alkyl chain. The irregularities in the coefficients for equation 2 as compared to equation 1 are attributed to intramolecular hydrogen bonding from the hydrogens of the alkyl chain to the carbonyl oxygen.

1-1094 EXPERIMENTS ON SLIP DAMPING AT ROUNDED CONTACTS. L. E. Goodman and C. B. Brown. Minnesota. Univ., Minneapolis, WADD TR 60-161, Pt. II. June 1961. 19p. illus. Contract: AF 33(616)-6828, Proj. no. 7351, Task no. 73521. A61-10253, pt. 2.

The apparatus described in Part I of this report has been modified and then has been used to obtain measurements of energy dissipation per cycle at the contact between a flat surface and spheres of various diameters. The dissipation occurred when the specimens were subject to various constant normal loads and tangential oscillating loads in the range $0.45 < \delta^* / \delta \text{ max} < 1$. The results agree well with the theoretical predictions of Mindlin and Deresiewicz in the range examined. Neither the sphere diameter nor the normal load magnitude appear as essential parameters. The results indicate the necessity of using surface rather than bulk elastic constants in the determination of contact damping. The material employed is AISI 316 stainless steel.

1-1095. INVESTIGATION OF SINTERABLE OXIDE POWDERS AND CERAMICS MADE FROM THEM. C. Hyde and W.H. Duckworth. Battelle Memorial Inst., Columbus, Ohio, WADD TR 61-262. June 1961. 20p. illus. Contract: AF 33(616)-6238, Proj. no. 7371. A61-10569

This program is concerned with the strength of nonporous monophase ceramics as a function of their microstructure, and with the basic nature of sinterable powders. Sinterable powders provide a convenient way to study a wide variety of microstructural effects without introducing variations in density or purity. MgO powders, prepared by calcining a high-purity basic magnesium carbonate, were studied as representative examples of sinterable powders. The temperature of calcination of the carbonate was found to have a critical effect on the density that could be obtained in sintered compact of the oxide. The density of compacts of each calcine increased during sintering until a ceiling density was reached after which grain growth occurred without further densification. Ceiling densities of 97-98% of theoretical were attained. Sintering in various atmospheres or for extended periods did not affect the the attainable density, but sintering in a moisture-free atmosphere reduced the temperature at which the ceiling density was reached. Indications were that sintering atmosphere affected grain growth. The work demonstrated the importance of controlling processing variables to assure uniformly reproducible specimens for strength measurements.

1-1096. METAL CARBONYLS AND SUBSTITUTED METAL CARBONYLS. Peter Breisacher. Aerospace Corp., El Segundo, Calif. Laboratories Div., Rept. no. TDR-930(2210-12)TN-2. 8 Nov. 1961. 40p. Contract: AF 04(647)-930. 123 refs. A61-10531.

A summary is presented of the physical and chemical properties of the transition metal carbonyls and substituted carbonyls. Special emphasis has been placed on the grouping of compounds according to their reactivities with specific functional groups. Methods of preparation are presented, along with references to spectral data. This survey was made as support of the program on hydride investigations by atomic reactions.

1-1097. ORDERING IN OXIDE SOLID SOLUTIONS. H. H. Wilson. Clemson College, Clemson, South Carolina. Ceramic Engineering Dept., ASD TR 61-92. June 1961. 6p. Contract: AF 33(616)-6870, Proj. no. 7022, Task no. 73664. A61-10561.

A study was made of solid solutions formed from mixtures of magnesium oxide with manganese, iron, cobalt, or nickel oxide to determine if, by suitable heat treatment, ordering could be induced in certain selected compositions. Heat treatment consisted of firing the prepared solid solutions in suitable atmospheres at 200°C intervals from 200°C to 1200°C. The specimens were held at each temperature for 100 hrs and analyzed by x-ray diffraction to detect superlattice formation. No superlattices were found in the samples. It is possible that the lack of ordering might be due to either insufficient time at the proper temperature or to the maximum temperature being too low to allow the required ionic diffusion. Future work will include the use of extended times and higher temperatures. Also the use of mechanical stress to enhance diffusion will be investigated.

1-1098. PHOSPHINOBORINE POLYMERS. R. I. Wagner, A. B. Burg, and D. L. Mayfield. American Potash and Chemical Corp., Los Angles, Calif., WADC TR 57-126, Pt. V. May 1961. 234p. illus. Contract: AF 33(616)-6913, Proj. no. 7340, Task no. 73404. A61-10540, pt. 5.

Boron-Phosphorus Polymers. Treatment of triethylamine stabilized P-dimethylborophane polymer with a variety of reagents resulted in increased thermal stability. N-Halosuccinimides have been shown to be quite useful in synthesizing completely or partially B-halogenated borophane compounds, which could be readily substituted by reaction with certain organometallic reagents. Conditions for substitution of B-halogens with cyano radicals were also developed. Boron-Nitrogen Polymers. On pyrolysis unsymmetrically substituted borazenes showed significant disproportionation but no indication of linked-ring borazene polymers which were prepared by coupling reactions as were polyborazyl oxides. Two pseudoaromatic compounds were pyrolized in an effort to prepare linear borazene polymers. New Approaches to Thermally Stable Polymers. Prototype P-N bonded compounds were prepared from aniline, phenyl-, and diphenylphosphonyl chlorides, when diphenylphosphonyl azide, a polymer precursor, was found to be unexpectedly thermally stable. Polymers having Si-O-P, Si-O-C(=O)- and $CB(NC)_2$ (cont.)

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skeletons were prepared. Physical Chemistry. Neumayer thermistor and microbulliometric molecular weight apparatuses and differential thermal analysis equipment have been used to characterize and evaluate new compounds. Inorganic Polymer Components. New CF_3-P-O compounds and a new PCCP diphosphine have been made as possible polymer precursors. The new alkyltrifluoromethylphosphines and polyphosphines offer the opportunity to seek new kinds of R_2P-B-H polymers. Thiosiloxane Polymers. Attempts have been made to synthesize high molecular weight linear thiosiloxanes from the cyclic trimer, hexaphenylcyclotrithiosiloxane, by thermal and chemical ring opening reactions as well as reactions of silanethiols with chlorosilanes.

1-1099. SOLUTION RATES AND EQUILIBRIUM SOLUBILITY OF NICKEL AND IRON IN LIQUID LITHIUM. B. Minushkin. Nuclear Development Corp. of America, White Plaines, N. Y., Rept. no. NDA 2141-1. 30 June 1961. 37p. illus. Contract: NOnr-2857(00) Amend I. 21 refs. A61-10316.

The equilibrium solubility and solution rates of nickel and iron in lithium were measured in the temperature range from 540°C (1004°F) to 825°C (1517°F) and 662°C (1224°F) to 760°C (1400°F), respectively. The solution rates and solubility data were obtained by measuring the solute concentration, as a function of time of contact, using a liquid sampling technique. The equilibrium solubility-temperature relationship for nickel in lithium in the temperature range studied is accurately represented by $\log_{10} C_0$ (ppm Ni) = 8.44 - 4600/T(°K). The equilibrium solubility of iron in lithium is 27 ppm at 662°C and 85 ppm at 760°C. Both nickel and iron dissolve in lithium at a very high rate within the temperature ranges investigated. Saturation of the experimental system, which had a surface area-to-volume ratio of 0.57 cm^{-1}, occurred in less than 1/2 to 1-1/2 hr. The solution rate constants, α, which characterize the dissolution process for nickel were calculated from the concentration-time data using the equation $(dC/dt)_1 = \alpha_1 (A/V)(C_{01}-C_1)$. The solution rate constants for nickel in lithium, stirred at 54 rpm (0.22 ft/sec linear velocity), were 19 cm/hr at 680°C, 29 cm/hr at

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330°C, and 39 cm/hr at 780°C. A higher stirring rate of 485 rpm (2.0 ft/sec) increased the solution rate constants by 20-25% within approximately the same temperature range. The solution rate constant for iron in lithium at 662°C under nominally static conditions was estimated to have a lower limiting value of 2.5-3.0 cm/hr. The upper limit or the true value at 662°C could not be obtained from the present data. Stirring increased the solution rate constants of both nickel and iron. The solution processes, therefore, are believed to be at least partially "diffusion limited" over the range of temperature and stirring rates investigated.

1-1100. THE SYNTHESIS AND EVALUATION OF AROMATIC ESTER AS POTENTIAL BASE STOCK FLUIDS FOR GAS TURBINE ENGINE LUBRICANTS. Wallace E. Taylor, Enrique R. Witt, et al. Celanese Chemical Co., Clarkwood, Texas, WADD TR 60-913. Mar. 1961. 69p. illus. Contract: AF 33(616)-6786, Proj. no. 3044, Task no. 73314. 13 refs. A61-10180.

A number of carboxylic acid esters were synthesized and evaluated as base stock fluids for lubricants suitable for operation at bulk oil temperatures of 450°F to 500°F. Oxidation stability at these temperatures is required and suitable fluidity at -65°F is desired. Esters were prepared from aromatic and aliphatic acids with phenols, benzyl-type alcohols and 2, 2-dimenthylalkyl aliphatic alcohols. Their physical properties and thermal and oxidative stabilities were determined and could be correlated with their structural units. Phenol esters of aromatic and 2, 2-dimethylalkyl carboxylic acids were thermally stable at 750°F and oxidatively stable at 450°F without inhibitors; esters of non-alkylated phenols gave the best oxidative stabilities. Low temperature properties were very poor for the aromatic acid esters; their pour points were in excess of 70°F and many were high melting solids. Esters of 2, 2-dimethylalkyl acids gave fluids with pour points well below this level. One of these fluids, resorcinol dineoheptanoate, showed, when inhibited, excellent resistance to oxidation at 475°F. Its volatility was

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somewhat high and its pour point (-55°F) above the target property, but it demonstrated the possibilities of obtaining an ester fluid with the range of desired properties. Suggestions are given for future studies aimed at developing a similar, but less volatile ester.

1-1101. SYNTHESIS OF INTROGEN-CONTAINING AND HETEROCYCLIC FLUID SYSTEMS. PART II: THE PREPARATION OF TRIAZINE, QUINOLINE AND TERTIARY AMINO DERIVATIVES.
E. H. Kober, B. F. Clark, et al. Olin Mathieson Chemical Corp., New Haven, WADD TR 60-315, Pt. II. Apr. 1961. 102p. illus. Contract: AF33(616)-6342, Proj. no. 7340, Task no. 73404. A61-10255.

This report presents the results of an investigation towards the synthesis of nitrogen-containing and heterocyclic compounds as potential thermally stable base stock fluids. Work on substituted derivatives of melam and melem, earlier carried out under this contract and reported in WADD TR 60-315, was continued. It is concluded that in these two classes of compounds thermal stability approaching the 1000°F goal can only be obtained with substituents which impart very high melting points to the resulting compounds. Further investigations were concerned with the synthesis of substituted s-triazines, quinolines, benzo(h)-quinolines, and silicon-containing aromatic tertiary amines. Many preparations showed melting points below 100°C., some had good thermal stability at 800°F, but only few exhibited fair stability at 900°F which appears to be the upper thermal stability limit of these compounds.

1-1102. SYNTHESIS OF NEW PLASTIC MATERIALS FOR ROCKET NOZZLES. Normal Bilow, Richard I. Akawie, et al. Second Progress Report, 1 June-31 Aug. 1961. Hughes Aircraft Co., Components and Materials Lab., Culver City, Calif., Rept. no. P61-14. 15 Sept. 1961. Contract: AF 33(616)-8037. A61-11372.

Utilizing the typical nozzle design described in the first progress report, aerodynamic shear has been related to the longitudinal position of a rocket exhaust gas stream in a rocket nozzle. Standard free energies of reaction have been calculated for approximately 240 different reactions at temperatures of 1000°, 2000°, 3000°, and 4000°K. These calculations have been made on materials which are potentially useful in composite rocket nozzles in order to gain insight into methods for controlling degradation and promoting desirable reactions. Several polymers such as polyphenyl and polyphenylenesilane have been prepared for evaluation as rocket nozzle matrices. They were, however, too highly crosslinked to be useful molding compounds. Several intermediates useful in preparing other polymers have also been synthesized. These include acetylenedicarboxylic acid diamide, diaminomaleonitrile, oxalyl chloride, oxalyl bromide, 5,6-dicyanopyrazine-2,3-dicarboxylic acid, dicyanoacetylene, tetracyanobenzene, and cobalt carbonyl mercury complex. The char-forming characteristics of various

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metal boride, carbide, and nitride-filled phenolic resins have been examined. Titanium diboride, molybdenum diboride, and boron carbide in that order appear to have outstanding char-forming capabilities.

1-1103. THEORY AND APPARATUS FOR MEASUREMENT OF EMISSIVITY FOR RADIATIVE COOLING OF HYPERSONIC AIRCRAFT WITH DATA FOR INCONEL, INCONEL X, STAINLESS STEEL 303, AND TITANIUM ALLOY RS-120. William J. O'Sullivan and William R. Wade. National Aeronautics and Space Administration, Washington, D.C., NASA TR R-90. 1961. 24p. A61-10431.

The importance of radiation as a means of cooling high supersonic and hypersonic speed aircraft is discussed to show the need for measurements of the total hemispherical emissivity of surfaces. The theory underlying the measurements of the total hemispherical emissivity of surfaces is presented, readily duplicable apparatus for performing the measurements is described, and measurements for stably oxidized Inconel, Inconel X, stainless steel 303, and titanium alloy RS-120 are given for the temperature range from 600°F to 2000°F.

Aerospace Corporation, El Segundo, California. APPLIED RESEARCH MANAGEMENT ABSTRACT BULLETIN, compiled by Literature Research Group. November 1961. [131]p.
(Report TDR-930(2701-01)TN-1, Part I, No. 5)
(Contract AF 04(647)-930) Unclassified report

Part I, No. 5 is a bibliography, with abstracts, from unclassified literature presented on the subject of Flight Vehicle Power. Selected references in the field of materials are also included. All references are to primary sources.

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